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ACS-258

final report

Phase B Extension

SPACE SHUTTLE CONCEPTS

Volume 4
SCHEDULING DATA

DRA

Contract NAS 8-26362

Prepared for National Aeronautics and Space Administration
by Manned Space Programs, Space Systems Division

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LOCKHEED MISSILES & SPACE COMPANY, INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION
Sunnyvale, California

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FINAL REPORT
PHASE B EXTENSION
SPACE SHUTTLE CONCEPTS

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LOCKHEED MISSILES & SPACE COMPANY, INC.
SUNNYVALE, CALIFORNIA

FOREWORD

This is the final report of work accomplished by Lockheed Missiles & Space Company, Inc. during the four-month Phase B Extension Study of Space Shuttle Concepts for the National Aeronautics and Space Administration, Marshall Space Flight Center, under contract NAS 8-26362.

The basic Study of Alternate Space Shuttle Concepts (ACS) contract was initiated in June 1970 and extended in two phases through 15 March 1972. The basic contract effort was reported in LMSC-A989142, Alternate Space Shuttle Concepts Final Report, 4 June 1971; and a subsequent effort in LMSC-A995931, Alternate Concepts Study Extension Final Report, 15 November 1971.

This report describes the work accomplished during the last period of the contract, extending from 15 November 1971 to 15 March 1972, and is organized in accordance with the outline provided by the contract Data Requirements List Item MA-04.

The final report consists of five volumes:

Volume 1, Executive Summary
Volume 2, Technical Report
Volume 3, Costing Data
Volume 4, Scheduling Data
Volume 5, Development Requirements

CONTENTS

Section		Page
	FOREWORD	iii
	ILLUSTRATIONS	ix
1	SCHEDULING DATA SUMMARY	1-1
	1.1 Introduction and Background	1-1
	1.2 Master Schedule Approach	1-2
	1.2.1 Schedule Groundrules and Assumptions	1-5
	1.2.2 Report Requirements	1-6
	1.3 Conclusions and Recommendations	1-8
2	SPACE SHUTTLE PROGRAM DEVELOPMENT (WBS Level 2, L5)	2-1
	2.1 Introduction	2-1
	2.2 Space Shuttle Master Schedule Development	2-1
	2.2.1 Approach	2-1
	2.2.2 Rationale	2-2
	2.3 Groundrules and Assumptions	2-3
	2.3.1 NASA Direction (Ref: TD 3007, dated 24 November 1971)	2-3
	2.3.2 General Requirements	2-3
	2.3.3 Engineering	2-4
	2.3.4 Manufacturing	2-5
	2.3.5 Test	2-5
	2.4 Space Shuttle Phase C/D Master Program Schedule Milestones	2-6
	2.5 Space Shuttle Program Logic Network	2-7
3	ORBITER SYSTEM DEVELOPMENT (WBS Level 3, L5-02)	3-1
	3.1 Introduction	3-1
	3.1.1 Products and Services	3-3

CONTENTS (Continued)

Section		Page
	3.2 Orbiter System Development Schedule	3-3
	3.2.1 Schedule Rationale	3-3
	3.2.2 Schedule Risk	3-6
	3.3 Orbiter System Logic Network	3-7
4	EXTERNAL TANK SYSTEM (WBS Level 3, L5-07)	4-1
	4.1 Introduction	4-1
	4.1.1 Products and Services	4-1
	4.2 External Tank Schedule	4-2
	4.2.1 Schedule Rationale	4-2
	4.2.2 Schedule Risk	4-5
	4.3 External Tank Logic Network	4-5
5	ORBITER SUBSYSTEMS	5-1
	5.1 Orbiter Structures Subsystem (WBS Level 4, L5-02-02)	5-2
	5.1.1 Products and Services	5-3
	5.1.2 Schedule Rationale	5-3
	5.1.3 Schedule Risk	5-6
	5.2 Orbiter Propulsion Subsystem (WBS Level 4, L5-02-03)	5-9
	5.2.1 Products and Services	5-10
	5.2.2 Schedule Rationale	5-10
	5.2.3 Schedule Risk	5-13
	5.3 Orbiter Power Subsystem (WBS Level 4, L5-02-04)	5-17
	5.3.1 Products and Services	5-18
	5.3.2 Schedule Rationale	5-18
	5.3.3 Schedule Risk	5-21
	5.4 Orbiter Avionics Subsystem (WBS Level 4, L5-02-05)	5-25
	5.4.1 Products and Services	5-27
	5.4.2 Schedule Rationale	5-27
	5.4.3 Schedule Risk	5-30

CONTENTS (Continued)

Section		Page
5.5	Orbiter Environmental Control/Life Support Subsystem (EC/LSS) (WBS Level 4, L5-02-06)	5-33
5.5.1	Products and Services	5-33
5.5.2	Schedule Rationale	5-33
5.5.3	Schedule Risk	5-36
5.6	Orbiter Crew Compartment Subsystem (WBS Level 4, L5-02-07)	5-39
5.6.1	Products and Services	5-39
5.6.2	Schedule Rationale	5-39
5.6.3	Schedule Risk	5-40
5.7	Orbiter Installation, Assembly, and Checkout (WBS Level 4, L5-02-09)	5-43
5.7.1	Products and Services	5-43
5.7.2	Schedule Rationale	5-43
5.7.3	Schedule Risks	5-47
5.8	Orbiter Ground Tests (WBS Level 4, L5-02-10)	5-51
5.8.1	Products and Services	5-51
5.8.2	Schedule Rationale	5-51
5.8.3	Schedule Risk	5-53
5.9	Orbiter Facilities (WBS Level 4, L5-02-11)	5-57
5.9.1	Products and/or Services	5-57
5.9.2	Schedule Rationale	5-58
5.10	Orbiter System Support (WBS Level 4, L5-02-12)	5-63
5.10.1	Schedule Rationale	5-64
5.10.2	Schedule Risk	5-65
5.11	Orbiter Horizontal Flight Test (WBS Level 4, L5-06-01)	5-69
5.11.1	Products and Services	5-69
5.11.2	Schedule Rationale	5-69
5.11.3	Schedule Risks	5-70

ILLUSTRATIONS

Figure		Page
1-1	Guidelines and Assumptions per TD 3007, 24 November 1971 and Revisions, 7 January 1972	1-3
1-2	Engineering Development Phase	1-3
1-3	Test and Operations Phase	1-4
1-4	Critical Schedule Aspects	1-6
1-5	Major Work Breakdown Structure Elements	1-7
2-1	SS Phase C/D Master Phasing Plan	2-9
2-2	SS Phase C/D Program Logic Network	2-11
3-1	Orbiter Baseline Development Schedule	3-9
3-2	Orbiter System Logic Network	3-11
4-1	External Tank Schedule	4-7
4-2	External Tank Logic Network	4-9
5-1	Structures Subsystem	5-7
5-2	Propulsion Subsystem	5-15
5-3	Power Subsystem	5-23
5-4	Avionics Subsystem	5-31
5-5	Environmental Control/Life Support Systems	5-37
5-6	Crew Compartment	5-41
5-7	Installation, Assembly, and Checkout Schedule	5-49
5-8	Ground Tests	5-55
5-9	Facilities	5-61
5-10	System Support	5-67
5-11	Horizontal Flight Test	5-71

Section 1
SCHEDULING DATA SUMMARY

1.1 INTRODUCTION AND BACKGROUND

This volume of the Phase B Extension Study of Space Shuttle Concepts Final Report contains scheduling data for the subsequent phases of the development and operations program (Phase C/D) and presents the current assessment of schedule requirements in relation to Concept Definition and Program Definition aspects of the Space Shuttle. This Scheduling Data Summary consolidates elements of schedule and development planning analysis and summarizes pertinent conclusions and recommendations.

The current Phase B Extension Study began on 1 November 1971 and concentrated on a spectrum of alternate booster concepts and variations of the MSC-040A orbiter system. The initial spectrum of booster concepts included series-burn configurations of the ballistic recoverable pressure-fed (PFB) and LOX/RP flyback concepts and parallel-burn configurations of the pressure-fed and solid rocket motor (SRM) concepts with a Mark I/Mark II phased orbiter development approach.

The initial orbiter development requirements (Technical Directive TD-3003) were for a five-orbiter fleet, ATP of 1 June 1972, 76 months to FMOF in September 1978, and three alternate primary engines: J-2, J-2S, and HiP_c.

TD-3004 changed the ATP date to 15 June 1972, FMOF to 1 September 1978 for Mark I (77 months) with Mark II FMOF five years later, and modified the mission model. The horizontal flight test program was constrained to FTV-1.

TD-3007 changed the horizontal flight test program to include two vehicles, ATP to 1 June 1972, FMOF for Mark I to 1 March 1978 with Mark II FMOF four years later. The same engine alternatives applied.

Current baseline direction for the Final Report is ATP of 1 July 1972, no Mark I orbiter development and HiP_c engines for the orbiter only. This constitutes the basis for technical definition in Volume 2, for cost analysis and development planning analysis in Volumes 3 and 4, and schedule analysis in this volume.

The variety of alternate concepts proposed and the design variations within these concepts generate technical and programmatic issues that are difficult to resolve in the concept selection and program development areas. Continued evolution of the booster matrix and the orbiter aerodynamic configuration impose limitations on design maturity and depth of program definition that make detailed schedules inappropriate at this time. The schedules presented here are keyed to accomplish a timely availability of the Space Shuttle Program within the current funding constraints.

The purpose of this report is threefold: (1) to identify all products and services required to deliver a working Space Shuttle System within a specified time frame; (2) to disclose those activities which will contribute to achievement of major milestones, and (3) to identify risks at the program, system, or subsystem level where they are most likely to affect schedule attainment.

1.2 MASTER SCHEDULE APPROACH

The current schedule emphasis is based on the guidelines and assumptions summarized in Fig. 1-1. The schedules presented in following sections concentrate on the principal activities required to support the major test articles and phasing of subsystem need dates in the early phases of the program.

As shown in Fig. 1-2, the engineering design activity in the first 24 to 30 month period leads through phased design review milestones at subsystem levels supporting the orbiter PDR and CDR milestones. This effort is paced by a high degree of concurrency in development tooling and manufacturing to support the STV (Structural Test Vehicle), DTV (Development Test Vehicle), and PDM (Propulsion Development Module) modules off of production tooling, and by subsystem long-lead test hardware procurement to support assembly of the first orbital configured vehicle (FTV-2).

TD GUIDELINES

EXTERNAL TANK O4OA ORBITER

BASELINE PERFORMANCE – 15 x 60 BAY
- 65K PAYLOAD – DUE EAST, 100 NM
- 45K PAYLOAD – POLAR, 100 NM
- 25K PAYLOAD WITH ABES, 55 DEG/270 NM
- 40K RETURN PAYLOAD

ORBITER ENGINES – 3 HIP_c AT 470K_{VAC} EACH

PARALLEL AND SERIES BURN

PFB AND SRM BOOSTERS

CONCURRENT BOOSTER DEVELOPMENT

PHASE C/D START – 7/72

FHF – 1976

FMOF – 3/78

FLEET SIZE – 5 ORBITERS

LMSC ASSUMPTIONS

- 68-MONTH SPAN TO FMOF
- SINGLE VEHICLE ENTERS HORIZONTAL FLIGHT TEST
- SINGLE VEHICLE SUPPORTS FMOF
- NO VERTICAL INCREMENTAL FLIGHT TEST
- FINAL ASSEMBLY AT PALMDALE
- FLIGHT TEST AT EDWARDS AFB
- OPERATIONS AT KSC

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Fig. 1-1 Guidelines and Assumptions per TD 3007, 24 November 1971 and Revisions, 7 January 1972

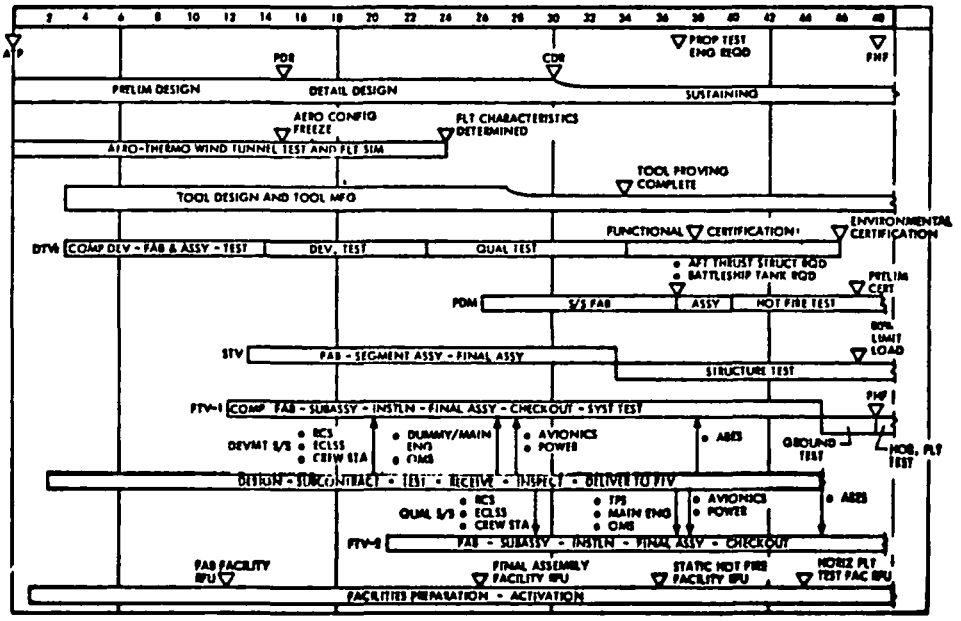

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Fig. 1-2 Engineering Development Phase

During the Test and Operations Phase, Fig. 1-3, Flight Test Vehicle No. 1 (FTV-1) is used only for the horizontal flight test program and is therefore a reduced configuration with only those subsystems necessary for this testing phase. FTV-2 is dedicated to manned orbital flight and carries a complete set of qualified subsystems but cannot be used to support horizontal flight testing because of critical schedule spans in facility compatibility and site activation. FTV-2 is not released from the final assembly facility to factory and acceptance test until preliminary certification is obtained for the PDM cold flow and cluster static hot fire, demonstration of 80 percent limit load in STV, and the first flight of FTV-1. FTV-2 is the first vehicle through complete CI and DD-250, and following this milestone will be used to accomplish the launch facility and GSE checkout. It is not being counted on to support the horizontal flight test program although it does provide backup capability to complete this program.

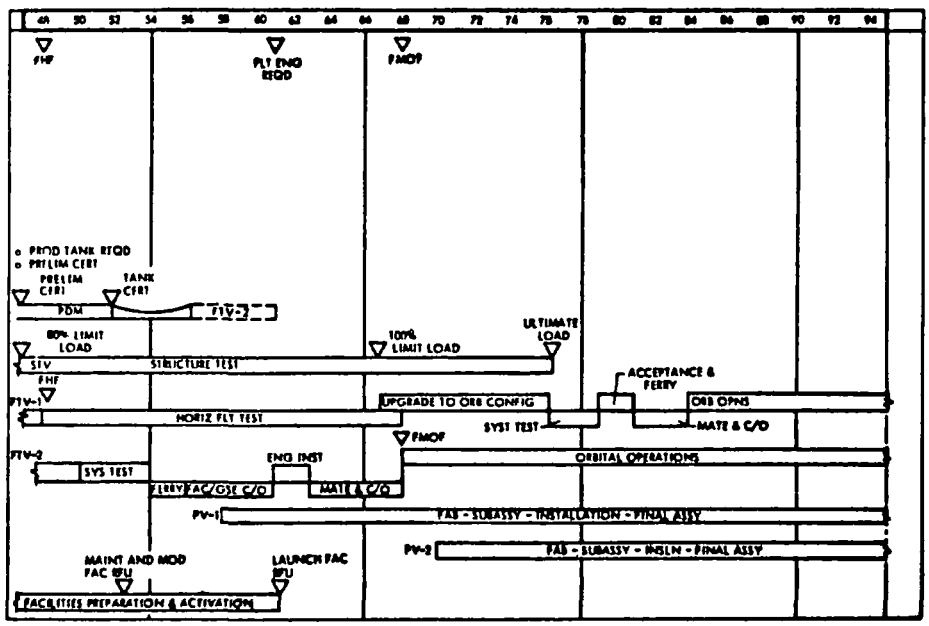

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Fig. 1-3 Test and Operations Phase

The previous development planning considerations lead to an identification of the critical paths and schedule aspects in Fig. 1-4. Any one of the selected areas can become the critical path, and where release of the first flight article from final assembly is concerned, two or more paths can be identified. At present, the primary rocket engine for the orbiter is the pacing item. Planned engine deliveries based on March 1972 go-ahead are understood to be as follows: propulsion test engine set for PCM in 42 months, functional test engines shortly after for installation at final assembly of FTV-2, and flight engine set 9 months later. The most critical requirement is for propulsion test engines about 36 months into the program to support the PDM assembly and cold-flow and static hot fire test span, which presently allows a minimal 12 months to preliminary certification of the integrated propulsion system and subsequent release of FTV-2. There is much less urgency in delivery of flight engines which are not required on the baseline schedule until installation at KSC just prior to the verification firing and launch preparation for FMOF. This identifies the most significant critical path.

Aerothermodynamic configuration development is also on a critical path branching from FHF of FTV-1, another contingency milestone for release of the first complete flight article (FTV-2) from final assembly. Slippage in either aerodynamic configuration freeze or engine deliveries could force an undesirable release of FTV-2 prior to design verification testing and lead to expensive field modification concurrently with other program activities on the downslope of the funding profile.

1.2.1 Schedule Groundrules and Assumptions

The following schedule groundrules apply in the delineation of schedules, networks, and narrative descriptions in this report:

- Major program activities and key milestones are shown as part of the Master Phasing Plan and are oriented to the NASA-approved program WBS for this contract.
- Program Logic Networks and System Logic Networks are activity oriented with activity times shown in weeks. All schedules are bar chart-type and are based on the Program Logic Network. The schedules, so developed, may be correlated with the costing data presented in Volume III.

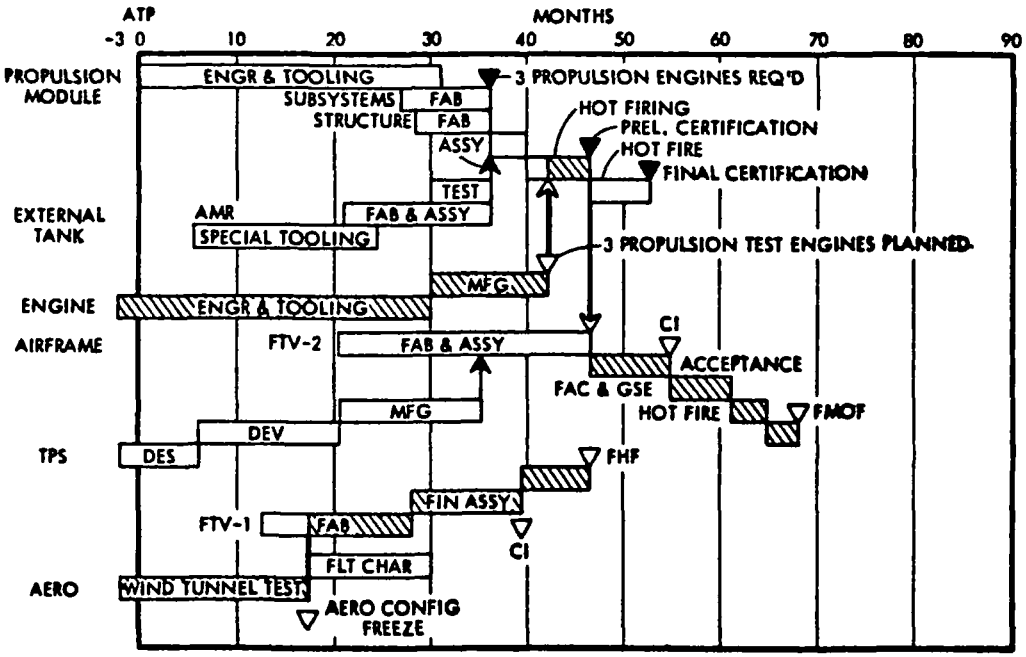

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Fig. 1-4 Critical Schedule Aspects

- All Networks and Schedules are developed to provide as much visibility and traceability as possible and will be supplemented by narrative descriptions of activities and analysis of potential risks at the system or program level where they are most likely to occur.
- The Shuttle System elements and supporting subsystems that are essential to the development and operation have been definitized in the program Work Breakdown Structure (WBS). The WBS summary is shown in Fig. 1-5 to level 4. Schedules will be shown in following sections for the solid boxes. The WBS dictionary is presented in the Cost Report, Volume 3 of this Final Report. The NASA-approved WBS for our study is presented in the Appendix of this volume.

1.2.2 Report Requirements

This report is based on the following contractual data requirements:

The Data Requirements List requires a Master Phasing Plan for the Space Shuttle Program, Program Logic Networks, and Subsystem Schedules that form the basis for schedule/cost correlation for each system or subsystem when used in conjunction with

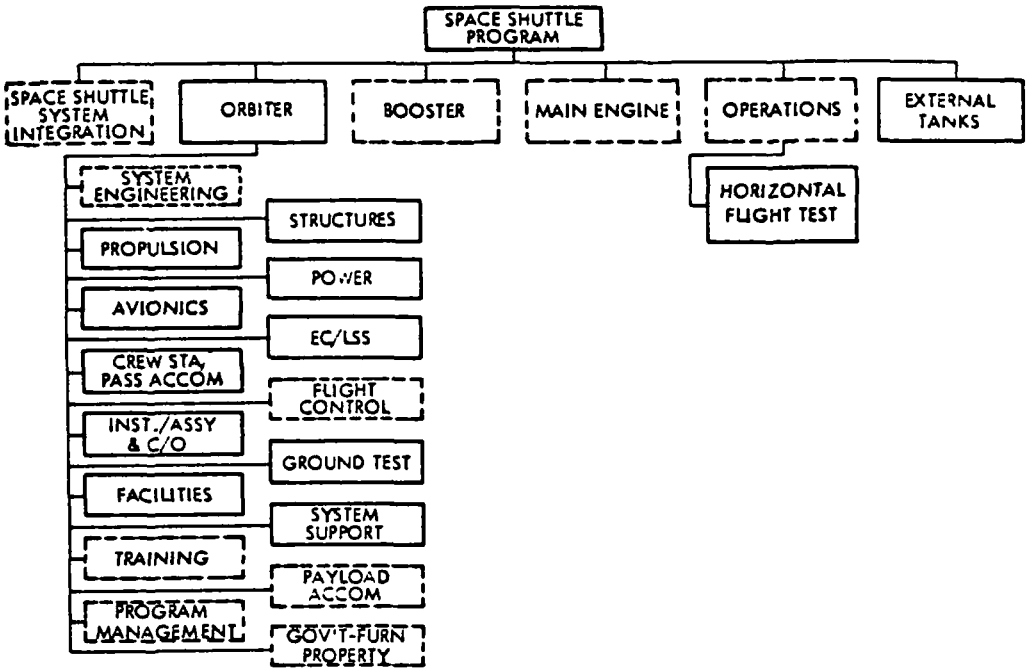


Fig. 1-5 Major Work Breakdown Structure Elements

their corresponding funding curves. The Master Phasing Plan is time phased, shows major activities, and relates these to key milestones from ATP through contractor support to the operational phase.

The Program Logic Networks are a graphic display which disclose specific system/subsystem integration at any time throughout the contract span. The networks are activity oriented (functional) with activities times shown in weeks.

System/Subsystem Activity Schedules are required for each major hardware-oriented system or subsystem. The logic networks serve as a basis for the display of these system and subsystem activities and events. The intraschedule relationships of activities (functions) – i.e. display, fabrication, assembly checkout, test, and integration – are displayed with constraints between current and consecutive activities.

The following networks and schedules are included in this volume:

Networks

- Space Shuttle Program
- Orbiter System
- External Tank System

Schedules

- Space Shuttle Master Program
- Orbiter System
- External Tank
- Orbiter Subsystems
  - Structures
  - Propulsion
  - Power
  - Avionics
  - Environmental Control/Life Support System (EC/LSS)
  - Crew Compartment
  - Installation, Assembly, and Checkout
  - Ground Test
  - Facilities
  - Orbiter System Support
  - Horizontal Flight Test

1.3 CONCLUSIONS AND RECOMMENDATIONS

Schedule analysis to date indicates no strong discriminator among the matrix of configuration and concept alternatives traceable solely to schedule feasibility or development planning aspects. The master schedule milestones in recent planning iterations have provided overall schedule spans to FMOF of up to 78 months. Pressure for earlier flight dates and delayed program go-ahead have resulted in the present compressed 68-month schedule for completion of the DDT&E phase. The limited hardware specified in the baseline program provides for only a minimal horizontal flight test program supported by a single vehicle. Further, no provision is made for vertical

rocket-powered flight test, backup vehicle for launch site activation and FMOF, or full-duration propulsion system test of the first orbital flight. Therefore, a larger schedule risk exists than is desirable. The development risk associated with these constraints is treated in Volume 5.

The engineering development schedules presented in this volume are heavily front-end loaded. Factors contributing to this are:

- High degree of concurrency and overlap of FTV-1 and FTV-2
- Critical long-lead hardware items that require pre-PDR and pre-CDR release:
  - Tooling
  - Commitments
  - Subassembly fabrication
- Five critical milestones identified from Fig. 1-4
  - Aerodynamic configuration freeze after the start of FTV-1 fabrication
  - Main rocket engine deliveries for PDM testing at 42 months
  - Preliminary certification of integrated propulsion system
  - Manufacturing assembly spans based on conventional aircraft approaches
  - Release of FTV-2 from final assembly constrained by 80 percent limit load tests, preliminary hot firing certification, and FHF

All of these factors have put heavy pressure on the front end of the schedules. An innovative approach must now be made to compress these spans and relieve the front loading burden on engineering. Adoption of additional test activity recommended in Volume 5 to offset recognized development risks requires additional test hardware, particularly an additional vehicle in the early parts of the test and operations phase, to provide necessary time spans for overlapping test activities such as the FTV-2 cold-flow at MTF and facility and site activation at KSC. Also, to ensure schedule/cost success, priority development must be made in the areas of aerothermo/structural configuration, main rocket engines, TPS, and external tank manufacturing development.

Section 2

SPACE SHUTTLE PROGRAM DEVELOPMENT
(WBS Level 2, L5)

2.1 INTRODUCTION

The Shuttle Program Master Schedule identifies the principal phases and hardware elements of the Shuttle Program and their interrelationships and establishes program milestone dates and time span estimates for their achievement in a manner that permits the establishment of more detailed scheduling – the capability to status achievement and thereby control the development of the program.

The schedule presents the integrated activities and major milestones that depict the development of the shuttle system through engineering design, development, manufacturing, ground testing, and flight testing to the point of demonstrating operational capability. This schedule was used as the baseline for planning the activities for the development of orbiter system elements and to enable supporting schedules to be directly keyed to the Shuttle Program Master Schedule.

The shuttle system development logic narrative and network portray the logical order of the development phases of the program and related support equipment and establish the sequence, constraints, and interdependency of activities and events necessary to the achievement of an operational system. Space Shuttle System development logic and schedule are shown in Section 2. The orbiter system development logic and program master schedule are shown in Section 3.

2.2 SPACE SHUTTLE MASTER SCHEDULE DEVELOPMENT

2.2.1 Approach

(1) Establish groundrules, assumptions, and logic that are compatible with and that implement overall program development logic, requirements, and NASA program objectives, milestones, and mission model.

(2) Determine the number and purpose of the required flight test vehicles, operational vehicles, ground test articles, development hardware, and other supporting models and mockups necessary to perform the development and operational phases of the program.

(3) Establish a logical and achievable relationship between the engineering design/development process, the hardware fabrication/assembly process, and flight development phase that minimizes risks and ensures the delivery rate that fulfills program objectives.

(4) Determine the sequence of deliveries for flight test vehicles, operational vehicles, and other development and operational hardware that meets the program requirements, constraints, and interdependencies established by the program development logic and analyses.

(5) Apply the analyses of schedule historical data from other programs that are similar to the shuttle in purpose, performance, size, complexity, and operational use (e.g., Apollo, Saturn S-V Vehicle, S-3A, C-5A, L-1011, and C-141) as a "test" of the time span estimates, functional interrelationships, and phasing of development activities.

2.2.2 Rationale

The engineering design process and design reviews (PDRs and CDRs) are time-phased to permit the detail design and specification releases to support the procurement and vehicle manufacturing modular buildup concept. The vehicle modules are large sections of the structure that include subsystem components. They are assembled and checked out, then subsequently mated to produce the complete vehicle, and culminate with final systems installation, integrated systems checkout delivery, and initiation of preflight activities.

The phasing of the first flight vehicle through the manuracturing process, prior to the structural and propulsion development module test articles was necessary to meet the first horizontal flight date of July 1976. However, this sequence allowed time for structural static testing up to 80-percent limit loads before the first horizontal flight.

The PDM test article, utilized to develop the main engine cluster(s) and their propellant feed and pressurization systems, is a prerequisite to the first manned orbital flight, scheduled for 1 March 1978. Current analyses show a requirement for 12 months of static firing tests for the orbiter with final certification of the hot firing scheduled for November 1976.

Development and certification testing of subsystems and components will be accomplished on a selective basis and is so scheduled as to allow the required portions of subsystems to be qualified incrementally to support the first horizontal flight and subsequently, the first manned orbital flight. The certification of subsystems to support the first horizontal flight is critically amplified by the July 1976 flight date.

The Shuttle Program flight test development phase will be accomplished with two orbiters (FTVs) and one booster. FTV-1 is used initially in a conventional aircraft type test program that will evaluate the subsonic horizontal flight envelope. FTV-2 will briefly supplement the horizontal flight testing prior to its utilization in the launch site facility and GSE checkout. FTV-2 will be used for the first manned orbital flight (FMOF). The first booster will be utilized for the one unmanned booster flight test. The second booster will be used for FMOF. Following their use in the flight test program, FTV-1 and the booster will be refurbished and delivered to the operational inventory.

2.3 GROUNDRULES AND ASSUMPTIONS

The following are the groundrules, assumptions, and pertinent NASA directions that form the basis for developing the baseline Phase C/D master schedules, Fig. 2-1.

2.3.1 NASA Direction (Ref: TD 3007, dated 24 November 1971)

- First horizontal flight – CY 1976.
- FMOF – 3/1/78.
- Operational fleet will include five orbiters.
- NASA traffic model progressively increases the yearly flight rate to conduct a total of 445 flights in 10 years.

2.3.2 General Requirements

- Schedule planning is to be designed to minimize DDT&E costs.
- FMOF is planned to occur 1 March 1978 with the first horizontal flight (FHF) in July 1976.
- The orbiter baseline configuration is the O4OA-L4 vehicle. The baseline booster is the series-burn PFB vehicle.

- Space Shuttle requirements consist of:
  - Five orbiter vehicles (2 for flight testing)
  - One orbiter structural test article (STV)
  - One orbiter propulsion development module (PDM) for main propulsion cluster development
- Vehicle quantity requirements and production rates consider a 7-day average total mission cycle for orbital flights.
- Shuttle program go-ahead (ATP) is assumed to be 1 July 1972. Immediately following go-ahead, a three-month period will be used to resize the orbiter, booster, and external tanks, to definitize the Shuttle management and technical approach, to implement proposed plans for fulfilling program requirement and objectives, and to define subsystems to the depth necessary for PDR on 1 October 1972.
- Main engine, airbreathing, and orbital maneuvering engine simulators, with physical interfaces identical to flight engines, will be used for manufacturing, assembly and installation processes when necessary before the delivery of flight engines. Simulators are also required for FTV-1 to fulfill mass and cg requirements during the horizontal flight test program.
- The thermal protection system used will be an RSI system, LI-1500.
- No procurement will occur prior to the orbiter PDR (at month 15) unless identified and approved as a long-lead procurement requirement.

2.3.3 Engineering

- Orbiter and booster vehicle PDR will occur at 15 months after Phase C/D go-ahead and will be preceded by individual subsystem PDRs. PDR for the orbiter vehicle airframe will occur 12 months after Phase C/D go-ahead.
- PDR for other orbiter support elements (e.g., GSE) occur 24 months after Phase C/D go-ahead.
- Start of orbiter vehicle detail release is 15 months after Phase C/D go-ahead.
- Start of orbiter detail design release for the airframe will occur 12 months after Phase C/D go-ahead.
- Orbiter CDR and 90 percent engineering release occur 30 months after Phase C/D go-ahead.
- Time span between the orbiter PDR and CDR will be 15 months.
- CDR for other orbiter support elements, e.g., GSE will occur at 35 months. CDR for the external tanks occurs at 37 months.
- Booster CDR occurs at 30 months.
- Orbiter and booster components, subsystems, and support systems will be qualified and/or flight certified on an incremental basis, and will be completed one month before the first horizontal and first manned orbital flights.

2.3.4 Manufacturing

- Manufacturing rate between the major test articles and the flight vehicles will be based on minimizing duplication of major structural assembly tooling.
- Orbiter main and orbital maneuvering engines for FTV-2 will be delivered with full instrumentation, ready to install eight months prior to FMOF. FTV-2 is undergoing facility and GSE checkout just prior to the engine installation.
- Orbiter and booster manufacturing flow times are based on a 5-day, 2-shift operation with selective 5-day, 1-shift operations, as applicable.

2.3.5 Test

- Flight test operations will be based on 5-day, 2-shift operations, with selected 3-shift operations, as required.
- Main engine final flight certification will be completed prior to the first manned orbital flight.
- Vacuum chamber testing of a complete vehicle under simulated environment is not a requirement.
- Preferry ground and flight testing to the extent necessary to demonstrate ferry airworthiness will be accomplished on all vehicles.
- All shuttle development flight tests will be manned operations.
- The development flight test program will be limited to two orbiter and one booster vehicles.
- Two launch pads will be available to support the orbiter and booster flight vehicle static firing and launch flight operations.
- M&R turnaround span times will consider system/program maturation effects in predicting the point at which the two-week turnaround will be achieved and in predicting ultimate turnaround span times.
- Delivery of the orbiter structural test articles will allow a minimum of 13 months of structural testing (to 80 percent limit loads) prior to first horizontal flight.
- Delivery of the orbiter main propulsion test article (PDM) will allow a minimum of three months for test stand integration and nonfiring tests and a minimum of seven months for static firing tests leading to preliminary certification prior to FHF. Five more months of hot firing are planned, leading to final certification.

2.4 SPACE SHUTTLE PHASE C/D MASTER PROGRAM SCHEDULE MILESTONES

Activity	Schedule Date
Program	
Phase C/D go-ahead	Jul 1972
Complete orbiter/booster resizing and definition of management and technical approach to Phase C/D Program with NASA - PRR	Oct 1972
System requirements review (SRR)	Jan 1973
Start preliminary design review (PDR) - orbiter airframe	Jul 1973
Complete PDR - orbiter vehicle	Oct 1973
Complete PDR - booster vehicle	Oct 1973
Complete PDR - orbiter system support elements	Jul 1974
Start critical design review (CDR) - orbiter subsystems	Jul 1974
Complete CDR and engineering 90 percent releases - orbiter	Jan 1975
Complete CDR and engineering 90 percent releases - booster	Jan 1975
Complete CDR - orbiter support elements	Jun 1975
Complete CDR - external tanks	Aug 1975
First horizontal flight (FHF)	Jul 1976
Unmanned booster launch	Oct 1977
First manned operational flight (FMOF)	Mar 1978
Engineering	
Start engineering preliminary design	Jul 1972
Part I CEI specs released	Oct 1973
Part II CEI specs released	Dec 1974
External test tank design release	Jan 1974
Manufacturing	
Start orbiter manufacturing development tooling	Jan 1973
Complete orbiter manufacturing development tooling	Jul 1973
Complete orbiter tooling	May 1974
Engines - Orbiter	
Propulsion test rocket engines required (3)	Nov 1975 to Jan 1976

Activity	Schedule Date
Functional test rocket engines required (3)	Apr 1976 to Jun 1976
1st set of flight-certified rocket engines required	Jul 1977

2.5 SPACE SHUTTLE PROGRAM LOGIC NETWORK

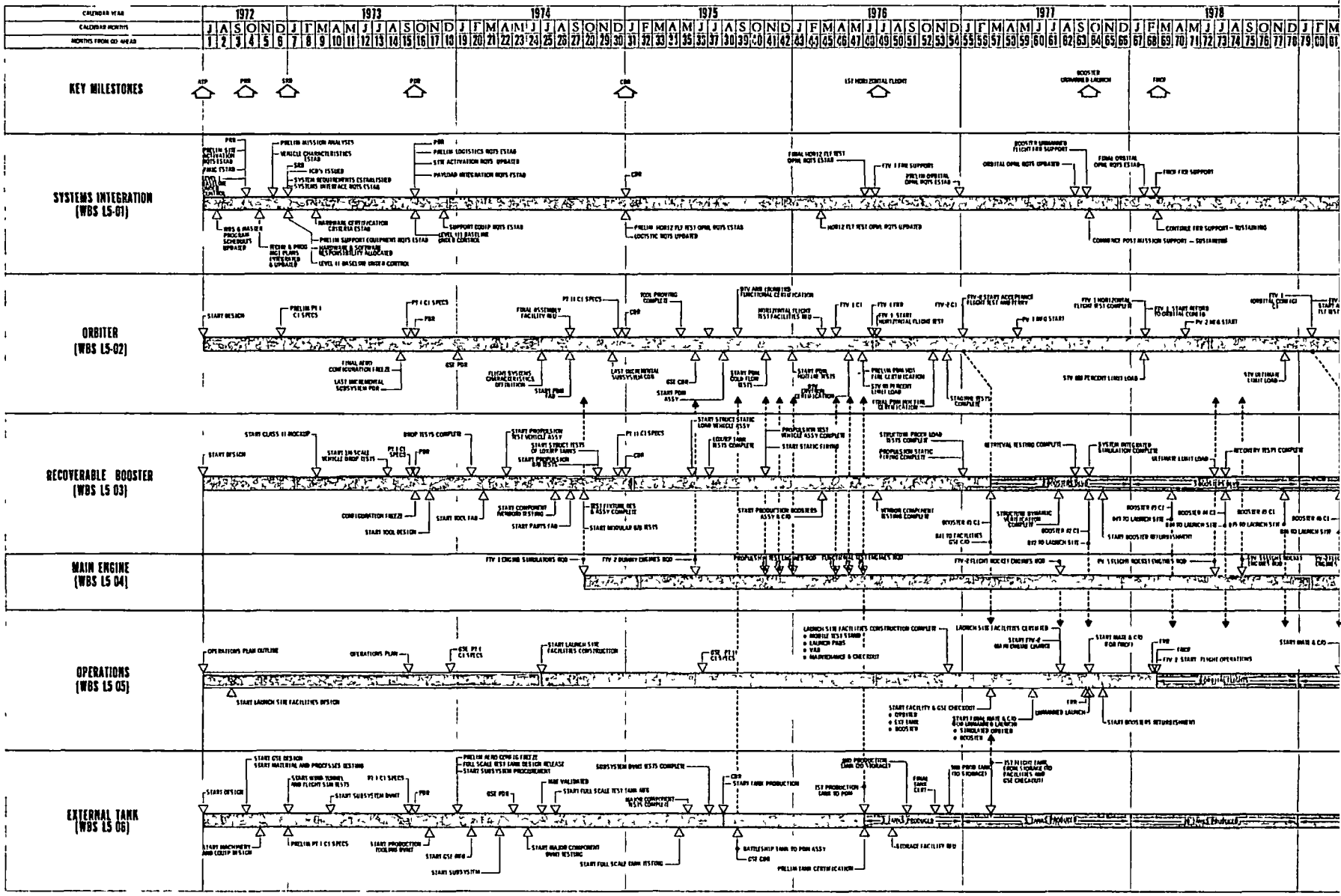
The Space Shuttle Development Logic is designed to portray the essential and logical order of primary phases, activities, and events requisite to the integrated development and operational utilization of the Space Shuttle system. This logical order represents a basic thread of program development flow and, as such, would not be significantly affected by the on-going iterative variations in either resource commitments or program schedules. The Space Shuttle Program Logic Network (Fig. 2-2) provides an overview of the total program for the activities of both the orbiter and PFB booster. The Orbiter System Logic Network in Section 3 provides the detailed events and activities affecting the orbiter system. The network for the external tanks (Section 4) provides similar detail for that subsystem.

In a broad sense, the Space Shuttle Development Logic displays the key program phases of (1) design and systems development, (2) flight test development, and (3) operations. Subsequent to contract go-ahead and the commitment of Government facilities and resources, the close interdependency between the main engine, orbiter, booster, payload module, and supporting systems development processes is summarized. Included in the Phase C/D development logic are all the necessary activities and events, such as, the shuttle system configuration and system requirements definition; selection and initiation of prime contractor Phase C/D activity; shuttle vehicle sizing and the integration activity during the design phase of prime elements such as main engines, the orbiter and booster systems, and facilities and support systems; the development of vehicle subsystems, ground test, and flight certification vehicles; the flight test development phase typified by the horizontal and manned orbital flight test programs; and ultimately, the operational employment phase of the shuttle system.

After the orbiter and booster systems requirements and configurations are established and sizing has been verified by initial wind tunnel tests and synthesis, subsystem and support systems Preliminary Design Reviews (PDRs) are conducted and culminate in the completion of the orbiter and booster vehicle preliminary design and program-level PDRs. Completion of the program-level PDRs sets the baseline for the shuttle system and the integrated functional and physical interface requirements. This permits them to be documented and approved prior to initiating initial design releases for the orbiter and booster and the subsequent commitment to significant manufacturing and procurement. Completion of the orbiter and booster PDRs establishes the requirements and preliminary design definition for the major elements of the shuttle system sufficiently to permit the start of procurement and fabrication of the test hardware required for subsystem and combined subsystems development test articles required for support of design verification and certification tests.

Completion of the subsystem Critical Design Reviews (CDRs) and orbiter/booster and main engine program CDRs, release of detail designs, fabrication of tooling, and activation of facilities allows Manufacturing to complete, assemble, and check out the major ground test and flight test articles and provides for subsequent events to be completed in support of the orbiter horizontal flight test programs (e.g., limit loads testing; partial and full certification of appropriate subsystems; combined systems testing; checkout and preflight test operations on the first flight vehicle; verification of systems performance/prediction analyses; and Flight Readiness Reviews). Subsequent to the first horizontal flights, completion of remaining subsystems certification is accomplished; remaining structural testing is concluded; main propulsion system static firing program is completed; final flight certification of main engines is achieved; payload module compatibility is demonstrated; orbiter/booster tank mating is demonstrated; manned space flight support systems are activated; and launch site and logistics support systems are activated. These are examples of major activities and events that occur before the first manned orbital flight. Finally, demonstration of operational capability takes place with all elements of the Space Shuttle System.

After the horizontal flight test program is completed, FTV-1 will be refurbished to orbital configuration and flight instrumentation will be removed. The booster used for the single booster development flight will likewise be refurbished. Both vehicles will then to into the operational inventory


CALENDAR YEAR
1972
1973
1974
1975
1976
1977
1978
CALENDAR MONTHS
MONTHS FROM GO AHEAD
KEY MILESTONES
ATP
PDR
SDR
PIR
CDR
1ST HORIZONTAL FLIGHT
BOOSTER UNMANNED LAUNCH
FMCF
SYSTEMS INTEGRATION (WBS LS-01)
ORBITER (WBS LS-02)
RECOVERABLE BOOSTER (WBS LS 03)
MAIN ENGINE (WBS LS 04)
OPERATIONS (WBS LS 05)
EXTERNAL TANK (WBS LS 06)

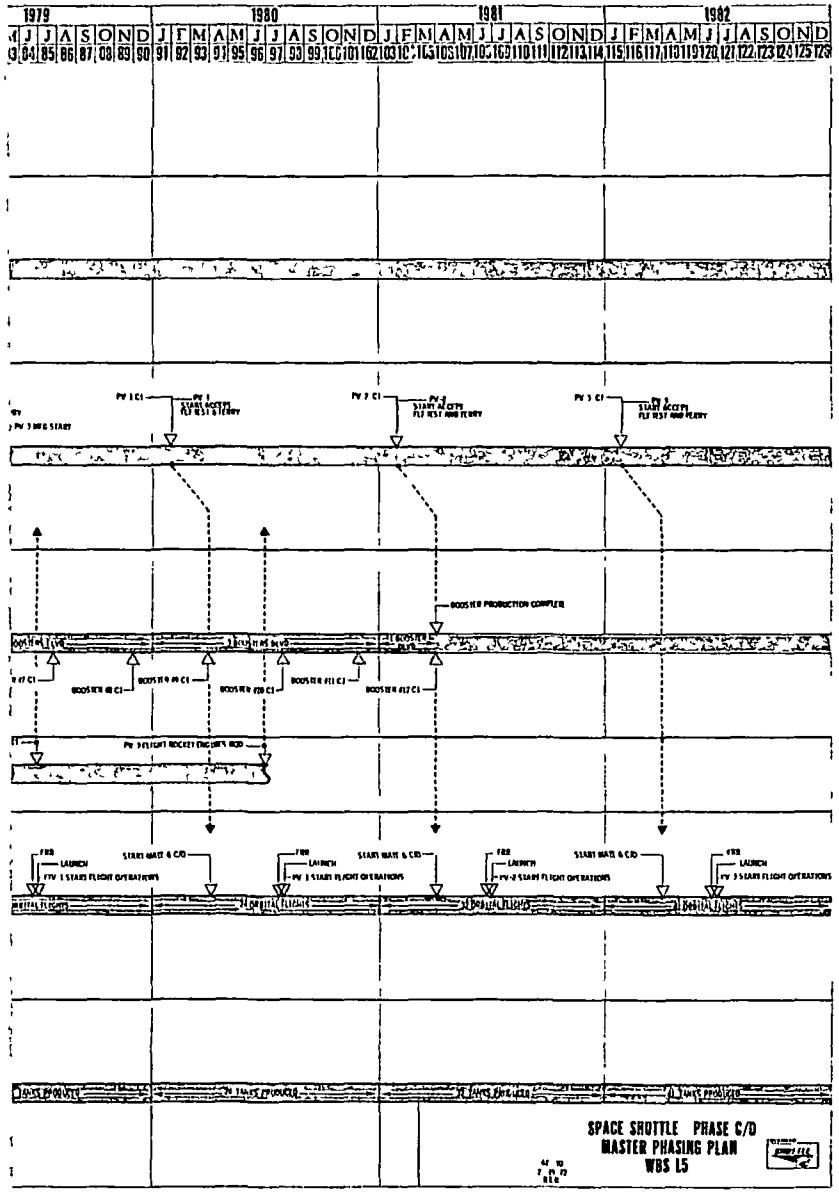


Fig 2-1 SS Phase C/D Master Phasing Plan

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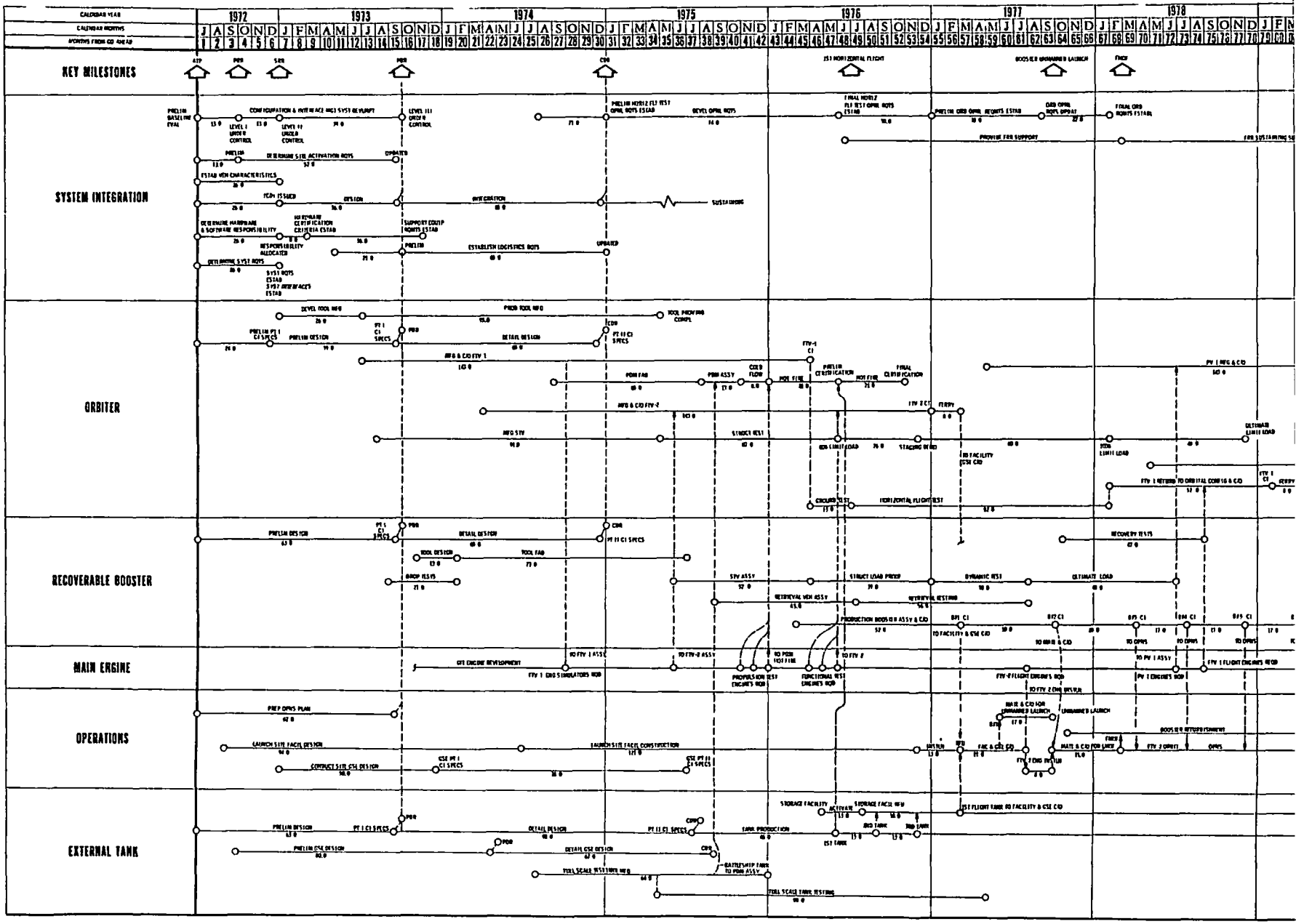
CALENDAR YEAR
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CALENDAR MONTHS
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MONTHS FROM GO AHEAD
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
KEY MILESTONES
ATP
PDR
SDR
PDR
CDR
251 HORIZONTAL FLIGHT
BOOSTER UNMANNED LAUNCH
FACF
SYSTEM INTEGRATION
ORBITER
RECOVERABLE BOOSTER
MAIN ENGINE
OPERATIONS
EXTERNAL TANK

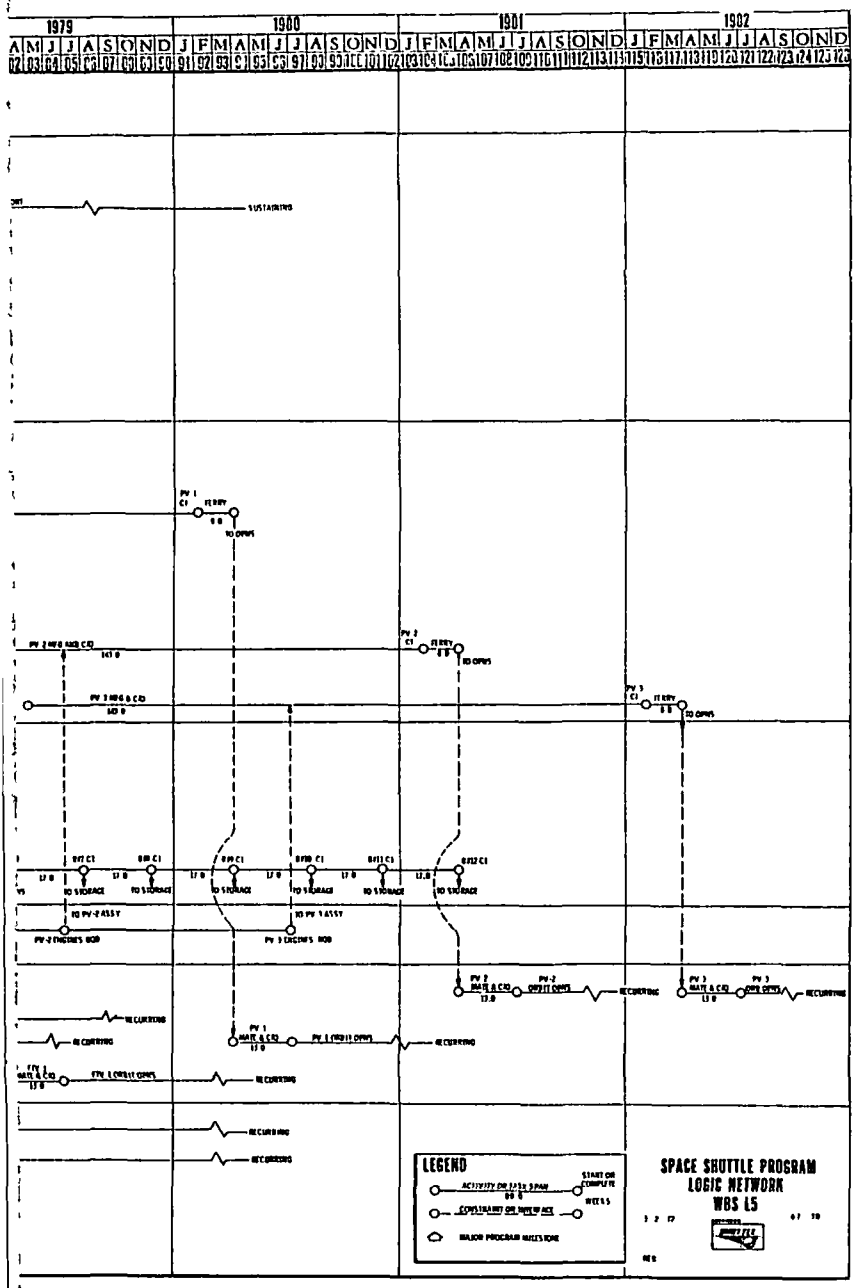

Fig. 2-2 SS Phase C/D Program Logic Network

Section 3

ORBITER SYSTEM DEVELOPMENT (WBS Level 3, L5-02)

3.1 INTRODUCTION

The purpose of the Orbiter System Development is to identify the principal program phases and hardware elements of the orbiter system and to establish schedule estimates and milestone dates to assure that the orbiter development program fulfills the objectives and meets the time phasing requirements of the Shuttle Program Master Schedule.

The orbiter program schedule, Fig. 3-1, presents the activities and major milestones that depict the development of the orbiter system through design, development, manufacturing, ground, and flight testing to the point of demonstrating operational capability. This schedule is used as the baseline for planning the activities required to achieve the most cost-effective design/development and operational orbiter program. All orbiter program supporting schedules (WBS Levels 4 and 5) are keyed to this master schedule, which in turn is keyed to the Shuttle Program Master Schedule.

The orbiter system, subsystems and supporting elements, essential to development and operation of the program have been definitized in the program Work Breakdown Structure (WBS). The orbiter system development logic network portrays the order of the development phases of the program and related support systems and establishes the sequence, constraints, and interdependency of activities and events that are necessary to the achievement of an operational orbiter system.

The engineering design/development process and design reviews are time-phased to permit the detail design and specification releases to support the manufacturing modular buildup concept; that is, large sections of the structure and their subsystems are assembled and checked out, subsequently mated to produce the completed vehicle, and culminate with final systems installation, an integrated systems checkout, delivery, and initiation of preflight activities.

The early time-phasing of the first flight vehicle in the manufacturing process, before the structural and main propulsion test articles, was necessary in order to meet the first horizontal flight date on July 1976. However, this sequence still allows for 13 months of static testing, up to 80 percent limit loads, before the first horizontal flight.

The propulsion development module (PDM) test article, utilized to develop the main engine cluster and its propellant feed and pressurization systems, is a prerequisite to the first manned orbital flight scheduled for March 1978. Current analyses show a requirement for a minimum of 12 months of static firing tests to adequately qualify the propulsion subsystems and acquire data to assess the compatibility of the orbiter and engine cluster configuration.

Development and certification testing of subsystems and components will be accomplished on a selective basis and scheduled in such a manner to allow portions of subsystems to be qualified incrementally, to support the first horizontal flight and subsequently, the first manned orbital flight.

The orbiter flight test development phase is accomplished with two vehicles. FTV-1 is used initially in a conventional airplane-type test program to evaluate the subsonic flight envelope. FTV-2 will complement the horizontal flight test program conducted with FTV-1 by performing a brief program of subsonic flight testing during its acceptance flight check and prior to its utilization in the facility and GSE checkout, captive hot fire, and mate and checkout at the launch site. FTV-2 is used for the FMOF.

Analysis of the development schedules indicates a heavy manpower loading and concentration of hardware early in the program. The critical paths of aerodynamic configuration freeze to FTV-1 fabrication leading to the first horizontal flight (FHF) and the path leading from engine development and delivery of propulsion test engines for PDM hot firing and preliminary certification prior to FHF puts a lot of pressure on the first complete flight article – FTV-2. Slippage in either aerodynamic configuration freeze or engine deliveries could force an undesirable release of FTV-2 prior to design verification testing and lead to expensive field modification concurrently with other program activities in the latter part of the DDT&E phase.

The WBS element for the Orbiter Vehicle includes all effort associated with the design, development, manufacture, test, tooling, assembly, installation, checkout, and procurement activities required to produce complete units which satisfy the requirements of all applicable specifications.

3.1 1 Products and Services

The deliverable products of this WBS element will consist of five orbiter vehicles (FTV-1, -2, PV-1, -2, -3) and the refurbishment services required to support a total of 445 missions. All DRL-required specifications, procedures, test reports, and technical manuals will be supplied. Spares and repair services will be provided as negotiated in the contract.

3.2 ORBITER SYSTEM DEVELOPMENT SCHEDULE

3.2.1 Schedule Rationale

The Orbiter Vehicle System design and development efforts will be initiated at ATP. During the following 90 days prior to Preliminary Requirements Review (PRR), systems engineering will be reviewing mission requirements, establishing design requirements and starting specifications. Preliminary design layouts will be underway; design analyses and trade studies will be in process; and general system requirements will be nearing formalization. Preliminary discussions will be started with potential suppliers and subcontractors. A materials and processes development test plan will be presented at PRR. At the same time, a comprehensive development test program plan including the requirements for wind-tunnel testing of scale model vehicles and tanks will be submitted. Material requests will accompany the plan defining all critical components and material required to support the development test program.

The period from PRR to System Requirements Review (SRR) will be devoted to a continuation of preliminary design and analyses of all vehicle elements which will result in an update of functional and design performance requirements. Coordination activities related to the ICDs will be progressing with the Customer and Associated Contractors. Configuration Item (CI) Part I specifications will be formulated and development

test unit (DTU) hardware fabrication will be started. Schedule-critical items will be procured, fabricated, or subcontracted as appropriate. Engineering mockups and "breadboard" models will be constructed as required. Preliminary contract negotiations will be conducted with all potential subcontractors. Construction of models for wind tunnel testing and thermal/wind tunnel test activities will continue. Preliminary design of ground support equipment (GSE) will be in work to the greatest extent possible in relation to the progress of vehicle design. Very preliminary planning will be started on special weld fixtures, assembly tools, handling equipment, and other associated machinery. Technical data developed during this period will help shape a definitive configuration for each element of the vehicle and this material will be used in support of SRR.

A major design and development effort will be expended on the Orbiter Vehicle System during the next nine months ending with Preliminary Design Review (PDR). Preliminary design and the required CI Part I specifications will be completed.

System engineering will be performing day-to-day technical requirements coordination and integration functions by supporting all aerospace engineering disciplines, reviewing hardware performance specifications, establishing design requirements, and integrating system reliability requirements into the evolving design and related development testing. Materials and processes development testing will be essentially complete except for the life tests on the various specimens. The aero configuration test program in the wind tunnel will have progressed to the point of configuration freeze and valuable design data will be available to support the PDR. Much of the detail design of the major elements and critical components will be completed. Fabrication of all development test items and selected qualification test hardware will be in process and production tool design and preliminary GSE will be progressing. Subcontracts will be awarded for selected long-lead time development items. Procurement of other schedule-critical items will be initiated. The ground test program plan will be updated and design and fabrication of a structural test vehicle (STV) and an "ironbird" will be started. The design and development activities to this point will be reflected in the comprehensive, cost-effective technical requirements of the Part I specifications presented to the Customer for approval prior to PDR. The approval of these specifications will constitute the

definition of the allocated baselines and will initiate configuration management, for accomplishment at the individual configuration item level, by control of the specified requirements for qualification and performance.

During the 15 months between PDR and Critical Design Review (CDR), the orbiter vehicle system engineering design, analyses, trade studies, and ICD coordination activities will be continuing. The wind tunnel flight simulation testing will be completed in this period resulting in a definition of the flight system characteristics. Production tool design and most of the GSE design will be completed. Production tool manufacturing and GSE fabrication will be in process. Nearly all component qualification testing will be finished. The STV will be starting into final assembly. The "ironbird" and a development test vehicle (DTV) will be assembled and the planned development testing utilizing these items will be finished. Fabrication will be started on a propulsion development module (PDM). The FTV-1 vehicle will be nearly finished with subsystem installation and ready for final assembly operations. FTV-2 vehicle detail fabrication will be complete and subassembly activities preparatory to subsystem installation will be underway. The orbiter vehicle final assembly facility will be ready for use in time to accommodate FTV-1. A critical design review of the Orbiter Vehicle System will be conducted at the end of 30 months into the program at which time the CI Part II specifications will be presented for approval. Customer approval of the specifications will define the subsystem product baseline and permit the conclusion of qualification testing.

The start of the horizontal flight test is the next major milestone and is scheduled for 18 months after CDR. This period encompasses completion of qualification testing, completion of tool fabrication, completion of GSE required for support of horizontal flight, and completion of the preliminary "hot-fire" program which utilizes the PDM and "battleship" tank. The "hot-fire" and flight test facilities will be ready as required. Sustaining the liaison engineering support will be provided to FTV-1 through final assembly, checkout, systems test, and ground test in preparation of first flight. The same support will be provided to FTV-2 through subsystem installation and final assembly.

The horizontal flight test program, utilizing FTV-1, will span a 19-month period and will be concluded approximately one month prior to the first manned orbital flight. The STV structural static and dynamic test program will continue until 100 percent limit load has been achieved. The PDM propulsion tests will continue through the final "hot-fire" series utilizing a production tank until final certification has been obtained. The last ground test activity in this period is the FTV-2 system acceptance test at the factory prior to ferry operations. An optional ground test for this period is propellant cold-flow test at MTF utilizing the FTV-2. There will be active liaison engineering support provided for FTV-1 during the horizontal flight test span. Also, support will be provided to produce the required engineering drawings, specifications, and procedures for retrofit of the vehicle to orbital configuration. Engineering, manufacturing, and test operations will also be performing the necessary functions for FTV-2 from factory checkout, systems test, acceptance flight check and ferry and through mate with booster, checkout and "hot-fire" at the launch site. Manufacturing will be fabricating and assembling components for PV-1. The launch site facilities and GSE will be checked out for compatibility with the total system. The GSE will be certified and the facilities will be identified as ready for use. Successful conclusion of FTV-1 horizontal flight test operations and the STV structural test program to 100 percent limit load are constraining on the first manned orbital flight schedule.

The first manned orbital flight with FTV-2 marks the start of the orbital operations phase of the program. During this last phase of the program, the engineering, manufacturing, and test operations personnel will provide sustaining and liaison activities required in support of subsystem installation, testing, and operations in all orbital vehicles which includes PV-1, PV-2, PV-3, and FTV-1. The STV structural test program will conclude with the ultimate load tests. The retrofit of the FTV-1 to orbital configuration will be a major engineering, manufacturing, and test activity during this period. A continuing effort will be the maintenance of the operational vehicles as contractually required.

3.2.2 Schedule Risk

The schedule risks associated with the Orbiter Vehicle System involve FTV-1 and FTV-2 hardware. The horizontal flight configuration vehicle for FTV-1 will be

fabricated and assembled before the qualification test program is complete which will significantly increase the amount of retrofit required for orbital flight. The problem is more serious for FTV-2 because this orbital vehicle will also be fabricated before the qualification testing is complete and no retrofit program is planned.

3.3 ORBITER SYSTEM LOGIC NETWORK

The orbiter system logic network (Fig. 3-2) is designed to display the significant and basic sequences, interrelationships, and constraints required to meet the management and technical goals within the Space Shuttle Program phases (i.e., design/system development, flight test development, and operations). It serves as the foundation for accomplishment of master schedule objectives and program assumptions and ground rules created to minimize orbiter system development risk and ensure schedule integrity.

Initially, an orbiter vehicle synthesis and sizing is performed with performance and operational requirements provided in a systems specification. This synthesis results in a refinement of the system specification and the shuttle configuration from which orbiter vehicle and preliminary subsystems configurations emanate. Subsequent to wind tunnel aerodynamic and thermal tests a baseline aerodynamic configuration is established. A progression of subsystem and support equipment Preliminary Design Reviews (PDRs) lead to the completion of orbiter vehicle preliminary design and system specification, CEI Part I. Concurrently, combined and subsystems development facilities and support equipment are activated. Following the orbiter vehicle and support systems PDRs, detail design is released, manufacturing tooling is activated, and subassembly commences on the orbiter ground and flight test vehicles. Prior to the delivery/acceptance of the first orbiter vehicle (FTV-1), the orbiter vehicle and support systems Critical Design Reviews (CDRs) are accomplished. These reviews conclude the phased subsystem and support systems CDRs, and include applicable subsystem development test results, the orbiter mockups, and appropriate system specifications (e.g., CEI, Part II).

Flight development testing commences with the first horizontal flight upon completion of the significant constraining program events and activities; e.g., assembly, checkout,

and ground testing of the flight vehicle; conducting requisite structural integrity and limit loads testing; completing required subsystem certification tests; crew training; and, activation of all necessary facilities and support equipment. The first horizontal flight and the horizontal test program provide a significant amount of risk-reduction technical development required prior to the first manned orbital flight (FMOF). Additional major events and activities required for FMOF are the completion of the remaining subsystem certification; conclusion of structural load limit testing; completion of the main propulsion system static firing program; final flight certification of main engines; activation of manned space flight support systems; and activation of launch site and logistics systems.

After the horizontal flight test program is completed, FTV-1 will be refurbished to orbital configuration. Flight test instrumentation will be removed and the retrofitted vehicle will enter the operational inventory.

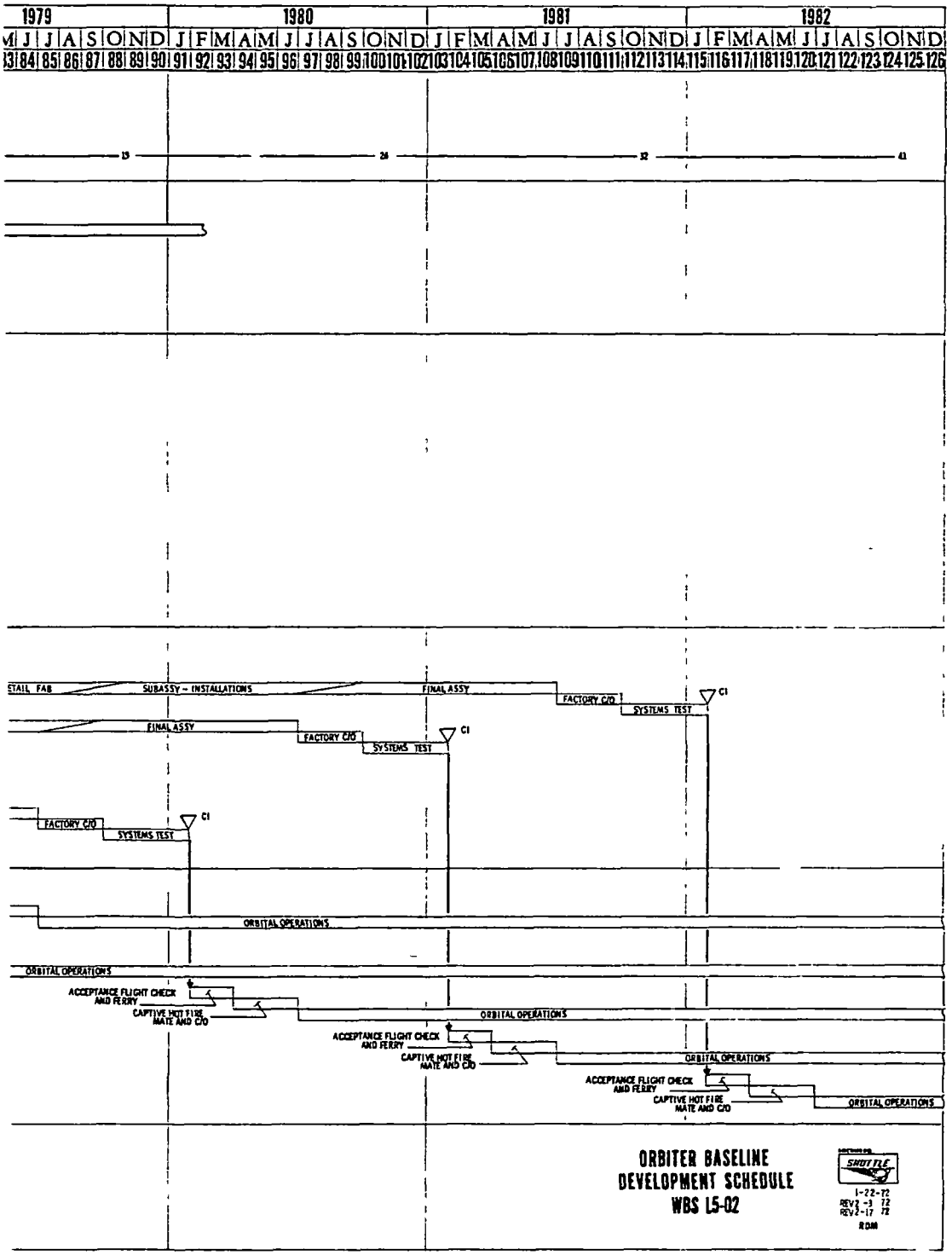

Fig. 3-1 Orbiter Baseline Development Schedule

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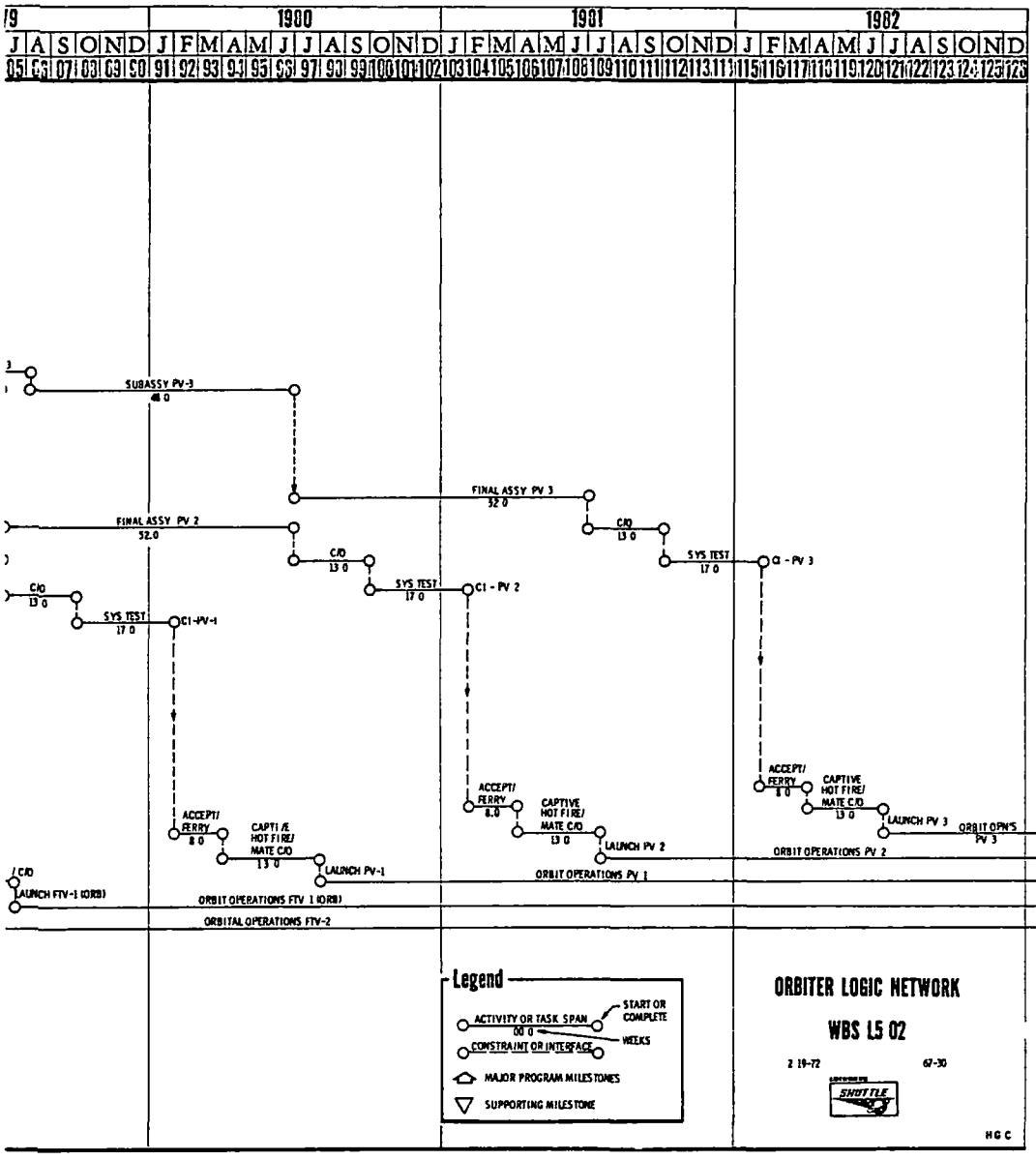

Fig. 3-2 Orbiter System Logic Network

Section 4

EXTERNAL TANK SYSTEM
(WBS Level 3, L5-07)

4.1 INTRODUCTION

The external tank schedule identifies the principal phases and hardware elements of this system and their relationships to the development of the Space Shuttle Program.

The tank schedule, Fig. 4-1, presents the activities and major milestones that display the development of the external tank system through design, development, manufacturing, ground test, and production of tanks to support the 445-flight mission model. The schedule is WBS oriented, although it is functional in nature due to the WBS level at which it is presented.

The external tank WBS element includes all engineering design, development, and analyses; tool design, fabrication and maintenance; manufacturing of detail parts and components, assemblies, and subassemblies; quality control, inspection; and procurement activities required to provide the external hydrogen and oxygen propellant tanks for the Orbiter Vehicle. This element also includes all test and support articles, design and fabrication of the mockups, fabrication of all spares and repair of hardware.

4.1.1 Products and Services

The deliverable products of this WBS element consist of the expendable external tanks required to support the five orbital vehicles for 445 missions, as well as the tanks required for ground testing. All DRL-required specifications, procedures, test reports, and technical manuals will be supplied. Spares and repair services will be provided as negotiated in the contract.

4.2 EXTERNAL TANK SCHEDULE

4.2.1 Schedule Rationale

The external tank design and development efforts will be initiated at receipt of ATP. During the following 90 days prior to Orbiter PRR, systems engineering will be reviewing mission requirements, establishing design requirements and starting specifications. Preliminary design layouts will be underway; design analyses and trade studies will be in process; and general subsystem requirements will be nearing formalization. A materials and processes development test plan for the tanks will be presented at PRR. At the same time, a comprehensive development test program plan for wind-tunnel testing of scale model tanks will be submitted.

The period from PRR to Orbiter System Requirements Review (SRR) will be devoted to a continuation of preliminary design and analyses of all tank elements. Coordination activities related to the tank ICD will be progressing with the Customer and Associate Contractors. A preliminary version of the Configuration Item Part I specification will be produced and will be available to support the SRR. Construction of tank models for wind-tunnel testing will be started and thermal/wind-tunnel test activities will be initiated. Preliminary design of ground support equipment (GSE) will be in work to the greatest extent possible in relation to the progress of the tank design. Very preliminary planning will be started on special weld fixtures, assembly tools, handling equipment, and other associated machinery. The technical data developed during this period will assist in preliminary sizing of the tank subsystem and will be used in support of SRR.

A major design and development effort will be expended on the tank subsystem during the next nine months that end with PDR. The preliminary design and the CI Part I specifications will be completed. System engineering will be performing day-to-day technical requirements coordination and integration functions by supporting all aerospace engineering disciplines, reviewing hardware performance specifications, establishing design requirements, and integrating system reliability requirements into the evolving design and related development testing. The tank subsystem ICD will have been fully coordinated with the Customer and Associate Contractors and completed in time for

submittal at PDR. Materials and processes development testing will be essentially complete for the life tests on the various specimens. The aero configuration test program in the wind tunnel will have progressed to the point that valuable design data will be available to support the PDR.

Tank subsystem development will be underway and preliminary GSE design will be approximately 50 percent complete. The system support equipment will be progressing with design and procurement activities will be nearly complete. When the CI Part I specifications are approved at or prior to PDR, this approval will constitute the definition of the tank subsystem allocated baseline and will initiate configuration management for accomplishment at the individual configuration item level by control of the specified requirements for qualification and performance. Design Release for the production of test tanks will occur three months after PDR.

During the 15 months between PDR and Orbiter Critical Design Review (CDR), the tank subsystem engineering design, analyses, trade studies, and ICD coordination activities will be continuing. The wind-tunnel testing will be completed early in this period, permitting a preliminary aero configuration freeze and release of the design for test tanks. The component development and fabrication will be complete and most of the structural component testing will be finished. A preliminary design review of the GSE will be conducted and detail design will be started. Fabrication of the full-size test tanks will be in process and the "battleship" tank will be completed and ready to support GSE testing. Tool design will be nearing completion with limited construction in process. All required special machinery and equipment will be installed and validated. The maturity of the tank subsystem engineering, coupled with the fact that well over half of the development testing will be complete, makes it feasible to conduct the Orbiter CDR as scheduled even though the tank CDR will be seven months later. The major concern will be the Orbiter/tank interface which should be frozen at this time. The results of all tank studies, analyses, and tests to date will be used in support of the Orbiter CDR.

The next 18-month period extending from Orbiter CDR to the first horizontal flight will encompass two significant milestones of the tank subsystem program. The first will be tank CDR, which will be supported by an updated ICD, completed design, CI Part II specifications and test data from the component development tests, subsystem

development and certification tests, GSE mechanical proof and electrical function tests, plus some preliminary data from the hydrostatic tests and the GSE propellant service tests. It is not anticipated that there will be any major design change during the period following Orbiter CDR, and that the mandatory changes which do occur will not affect the interface. The second major accomplishment of this period is completion of the first production tank subsystem approximately 10 months after tank CDR. The activities of this period, culminating in the first production item, include: sustaining and liaison engineering, comprehensive testing on four full-scale tanks, completion of the preliminary "hot-fire" program which utilizes the "battleship" tank, completion of design and CDR for GSE followed by most of the required fabrication. There is no direct schedule correlation between completion of the first production tank and the start of the horizontal flight test program.

The 20-month period ending with first manned orbital flight will include: the conclusion of the full-scale tank test program, the final "hot-fire" test phase utilizing either Production Tank No. 1 or Test Tank No. 2, resulting in Final Tank Certification, plus an optional cold flow test at MTF using FTV-2 and either one of the tanks noted before. At least 12 more production tank subsystems will be completed and placed in storage awaiting use by the time the first tank is flown at FMOF. If these tanks are complete in every detail (i.e., including ordnance items and thermal protection system) the storage space, environmental control, and safety problems will become a significant handling and scheduling problem when the number reaches the 20 planned for storage. One of the first three production tanks will be shipped to the launch site for mating and checkout with FTV-2 Orbiter in preparation for the first manned orbital flight and to support the checkout of the launch site facilities and GSE.

During the remainder of the orbital flight program, the production rate for the tanks will keep increasing until it reaches 60 units per year. Engineering will continue to provide sustaining and liaison activities as required in support of tank fabrication, test, and delivery to the launch site ready for mate and checkout. The tanks are expendable, so maintenance activities are associated primarily with the storage phase.

4.2.2 Schedule Risk

There are no identifiable schedule problems associated with having qualified production tank subsystems in time for planned use. LMSC's schedule problem will be related to establishing and maintaining a stable labor force which can economically produce an even flow of hardware without a series of extended work-week periods followed by cut-backs in the employment.

4.3 EXTERNAL TANK LOGIC NETWORK

The tank logic network (Fig. 4-2) displays the significant and basic sequences, interrelationships, and constraints required to meet the technical and management goals within the Shuttle Program. It serves as the foundation for the accomplishment of schedule objectives and program control to minimize the external tank system development risk.

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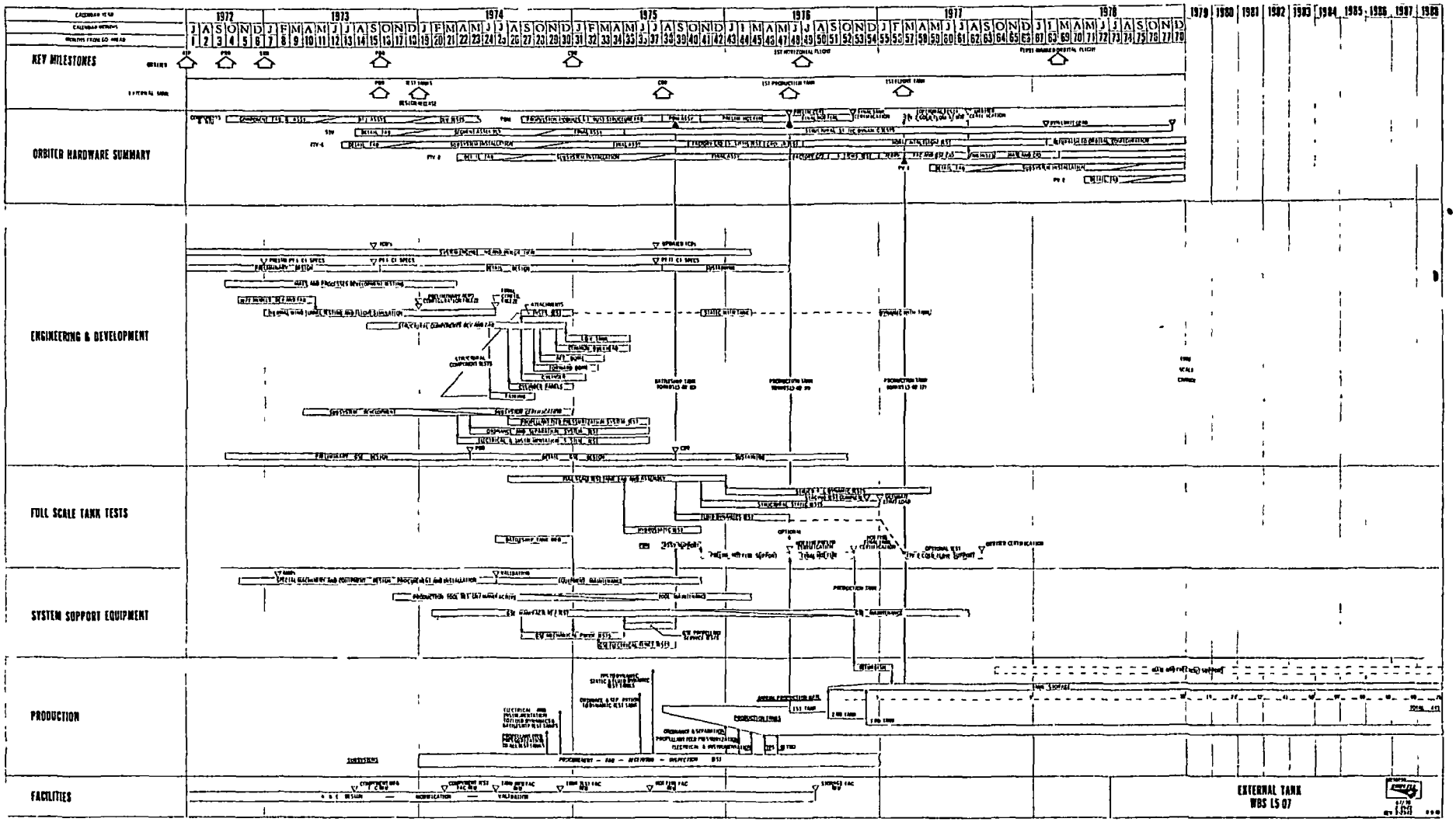

Fig 4-1 External Tank Schedule

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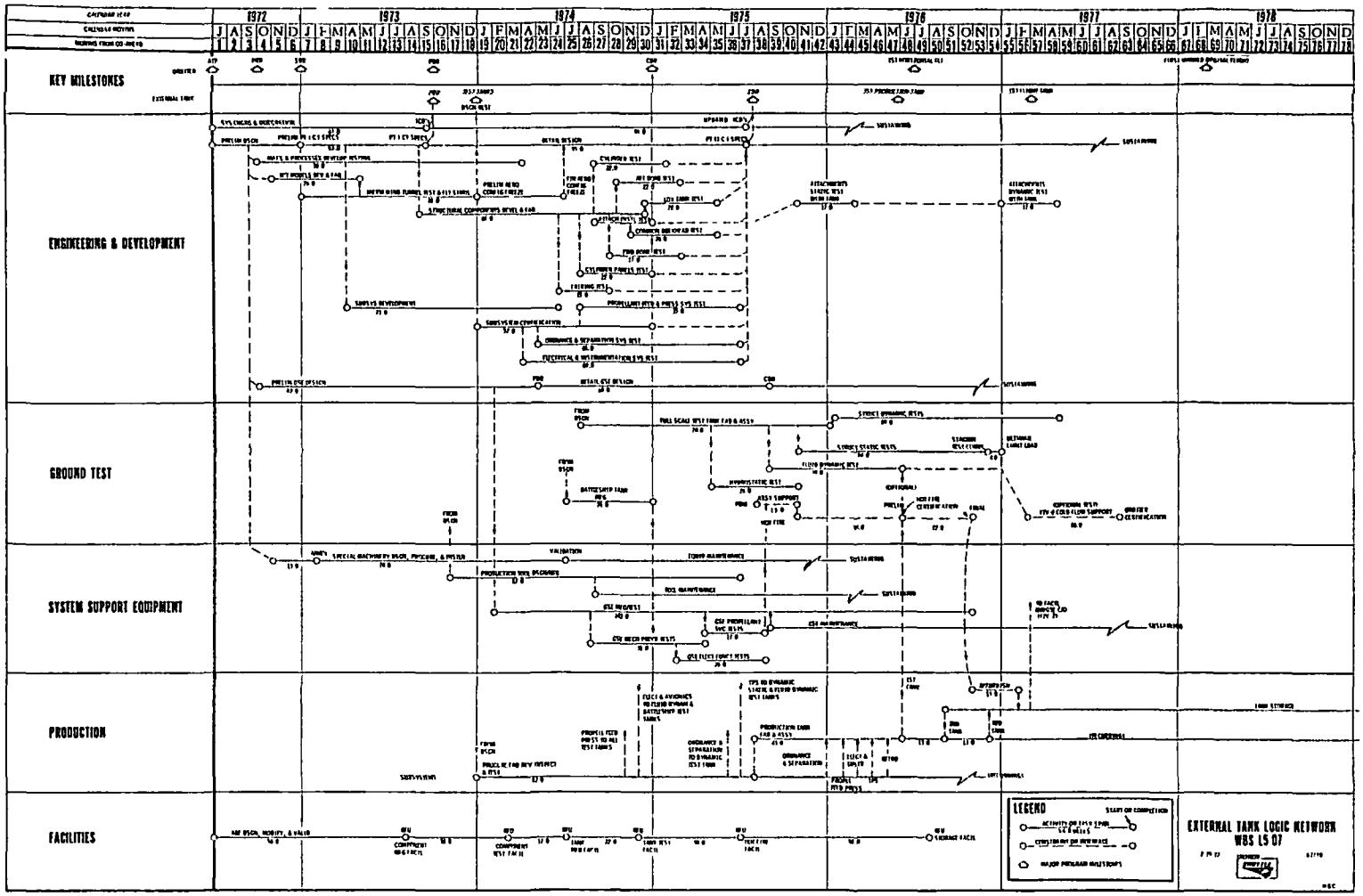


Fig. 4-2 External Tank Logic Network

Section 5

ORBITER SUBSYSTEMS
(WBS Level 4)

Schedules and development rationale are included in this section for the following orbiter subsystems:

Section	Orbiter Subsystem
5.1	Structures
5.2	Propulsion
5.3	Power
5.4	Avionics
5.5	Environmental Control/Life Support
5.6	Crew Compartment
5.7	Installation, Assembly, and Checkout
5.8	Ground Test
5.9	Facilities
5.10	System Support
5.11	Horizontal Flight Test

Discussions of the rationale used in developing the schedules or discussing the activities that occur will be described by major orbiter time spans, i.e., between PRR and SRR or between CDR and first horizontal flight. The schedules are WBS element-oriented rather than functionally oriented.

5.1 ORBITER STRUCTURES SUBSYSTEM (WBS Level 4, L5-02-02)

The orbiter structure subsystem is comprised of the primary airframe structure, aerodynamic surfaces, and major supporting structural elements. This subsystem consists of the following elements:

Primary Structure (Airframe)

- Forward Body, including crew cabin
- Mid Body, including payload bay
- Aft Body, including thrust structure

Aerodynamic Surfaces

- Wing Group
- Tail Group

Thermal Protection System

- Nose Cap
- Primary Insulation System, i.e. TPS
- Leading Edges

Landing Gear

Docking System

Separation/Attachment System

Payload Deployment

The WBS element for the Orbiter Structures Subsystem includes all effort associated with engineering design, development, test, and analysis; tool design, fabrication, and maintenance; manufacturing of detail parts and components, assemblies, and sub-assemblies; quality control; inspection; and procurement activities to provide the structures items identified above for installation and integration on the orbiter vehicle. This element also includes the effort required to provide all test and support articles, design and fabrication of the mockups, plus the fabrication of all spares and repair of hardware.

The tasks to be accomplished in the Structures Subsystem are shown in Fig. 5-1.

5.1.1 Products and Services

The deliverable products of this WBS element will consist of four complete structures subsystems (assembled structural and aerodynamic components) ready for installation and integration into orbiter vehicles FTV-2, PV-1, PV-2, and PV-3, plus a prototype subsystem which will be fabricated for FTV-1 use in horizontal flight test and then refurbished as necessary to orbital configuration later. All DRL-required specifications, procedures, test reports and technical manuals will be supplied. Spares and repair services will be provided as negotiated in the contract.

5.1.2 Schedule Rationale

The structures subsystem design and development efforts will be initiated at ATP. During the following 90 days prior to Preliminary Requirements Review (PRR) systems engineering will be reviewing functional requirements, establishing design requirements and starting specifications. Preliminary design layouts will be underway, design analyses and trade studies will be in process, and general structural requirements will be nearing formalization. A materials and processes development test plan will be presented at PRR. Material requests will accompany the plan, defining all critical components and material required to support the development test program.

The period from PRR to System Requirements Review (SRR) will be devoted to a continuation of preliminary design and analyses of all structural elements which will result in an update of functional and design performance requirements. Coordination activities related to the ICDs will be progressing with the Customer and Associated Contractors. Configuration Item Part I specifications will be formulated and Development Test Unit (DTU) hardware fabrication will be started. Schedule-critical items will be procured, fabricated, or subcontracted as appropriate. Development tool design and preliminary GSE design will be started and progressing to the greatest extent possible in relation to the progress of the structures subsystem design. The technical data derived during this period will be used in support of SRR.

A major design and development effort will be expended during the next nine months ending with Orbiter Preliminary Design Review (PDR). The structures PDR will be conducted three months earlier indicating the end of preliminary design and completion of the required Part I configuration specifications. System engineering will be performing day-to-day technical requirements coordination and integration functions by reviewing hardware performance specifications, establishing design requirements, and integrating system reliability requirements into the evolving design and related development testing. Much of the detail design of the major elements and critical components will be completed. The ground test program plan will be updated and the design and fabrication of a structural test vehicle (STV) will be underway. The approval of the CI Part I specifications will constitute the definition of the allocated baselines and will initiate configuration management, for accomplishment at the individual configuration item level, by control of the specified requirements for qualification and performance.

During the 15 months between Orbiter PDR and Critical Design Review (CDR), the structures subsystem engineering design, analyses, trade studies, and ICD coordination activities will have matured to the point that the critical design review of the subsystem can be conducted shortly after midway through the period. Immediately following structures CDR, the design will be released for start of fabrication of FTV-1 and the STV. By the end of this period at Orbiter CDR, production tool design and most of the GSE design will be completed. Production tool manufacturing and GSE fabrication will be in process. Nearly all component qualification testing will be finished. The STV will be starting into final assembly. The development test vehicle (DTV) will be assembled and the planned development testing using these items will be finished. The FTV-1 vehicle will be nearly finished with subsystem installation and ready for final assembly operations. FTV-2 vehicle detail fabrication will be complete and subassembly activities preparatory to subsystem installation will be underway. Also at the Orbiter CDR, the CI Part II structures specifications will be presented for approval. Customer approval of the specifications will define the subsystem product baseline and permit the conclusion of qualification testing.

The start of the horizontal flight test is the next major milestone scheduled for 18 months after CDR. This period encompasses completion of qualification testing,

completion of tool fabrication, plus the completion of FTV-2 structures fabrication, assembly, and installation. Sustaining and liaison engineering support of the structures subsystem will be provided to FTV-1 through final assembly, checkout, systems test, and ground test in preparation of first flight. The same support will be provided to FTV-2 through subsystem installation and final assembly.

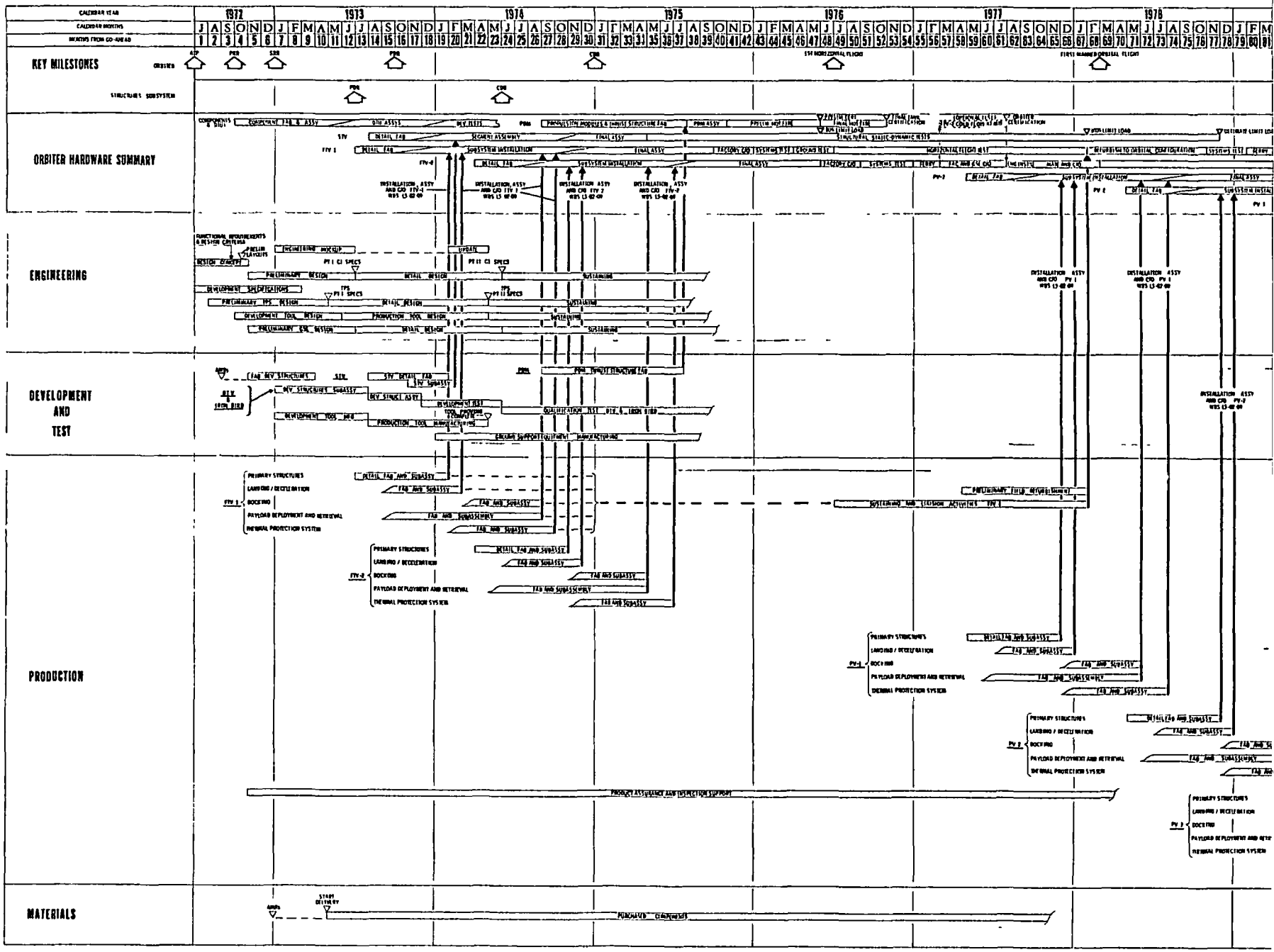
The horizontal flight test program, utilizing FTV-1, will span a 19-month period and will be concluded approximately one month prior to the first manned orbital flight. The STV structural static and dynamic test program will continue until 100 percent limit load has been achieved.

There will be active liaison engineering support of the structural subsystem provided for FTV-1 during the horizontal flight test span. Also, support will be provided to produce the required engineering drawings, specifications, and procedures for retrofit of the vehicle to orbital configuration. Engineering, manufacturing, and test operations will be performing the necessary functions on the structural subsystem for FTV-2 from factory checkout, systems test, acceptance flight check and ferry through mate with booster, checkout, and "hot-fire" at the launch site. Manufacturing will be fabricating and assembling structural components for PV-1. Successful conclusion of FTV-1 horizontal flight test operations and the STV structural test program to 100 percent limit load are constraining on the first manned orbital flight schedule.

The first manned orbital flight with FTV-2 marks the start of the orbital operations phase of the program. During this last phase of the program, the engineering, manufacturing, and test operations personnel will provide sustaining and liaison activities required in support of the structural subsystem installation, testing and operations in all orbital vehicles which include PV-1, PV-2, PV-3 and FTV-1. The retrofit of the FTV-1 to orbital configuration will be a major engineering, manufacturing, and test activity during this period. A continuing effort will be the maintenance of the operational vehicles structures as contractually required.

5.1.3 Schedule Risk

The schedule risks associated with the structural subsystem involve FTV-1 and FTV-2 hardware. The horizontal flight configuration subsystem for FTV-1 will be fabricated and assembled before the qualification test program is complete, which will significantly increase the amount of retrofit required for orbital flight. The problem is more serious for FTV-2 because this orbital subsystem will also be fabricated before the qualification testing is complete and no retrofit program is planned. The first 23 months of the schedule are the most critical as hardware and tooling are being fabricated prior to CDR. Close coordination must be maintained between the design engineers and manufacturing and test personnel to assure readiness as subsystems are available for installation.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ORBITER HARDWARE SUMMARY
ENGINEERING
DEVELOPMENT AND TEST
PRODUCTION
MATERIALS
PDR
CDR
ATP
SRR
FFT
ROLLOUT
FIRST MANNED ORBITAL FLIGHT
PRIMARY STRUCTURES
LANDING / DECELERATION
DOCKING
PAYLOAD DEPLOYMENT AND RETRIEVAL
THERMAL PROTECTION SYSTEM
PRODUCT ASSURANCE AND INSPECTION SUPPORT
PURCHASED COMPONENTS

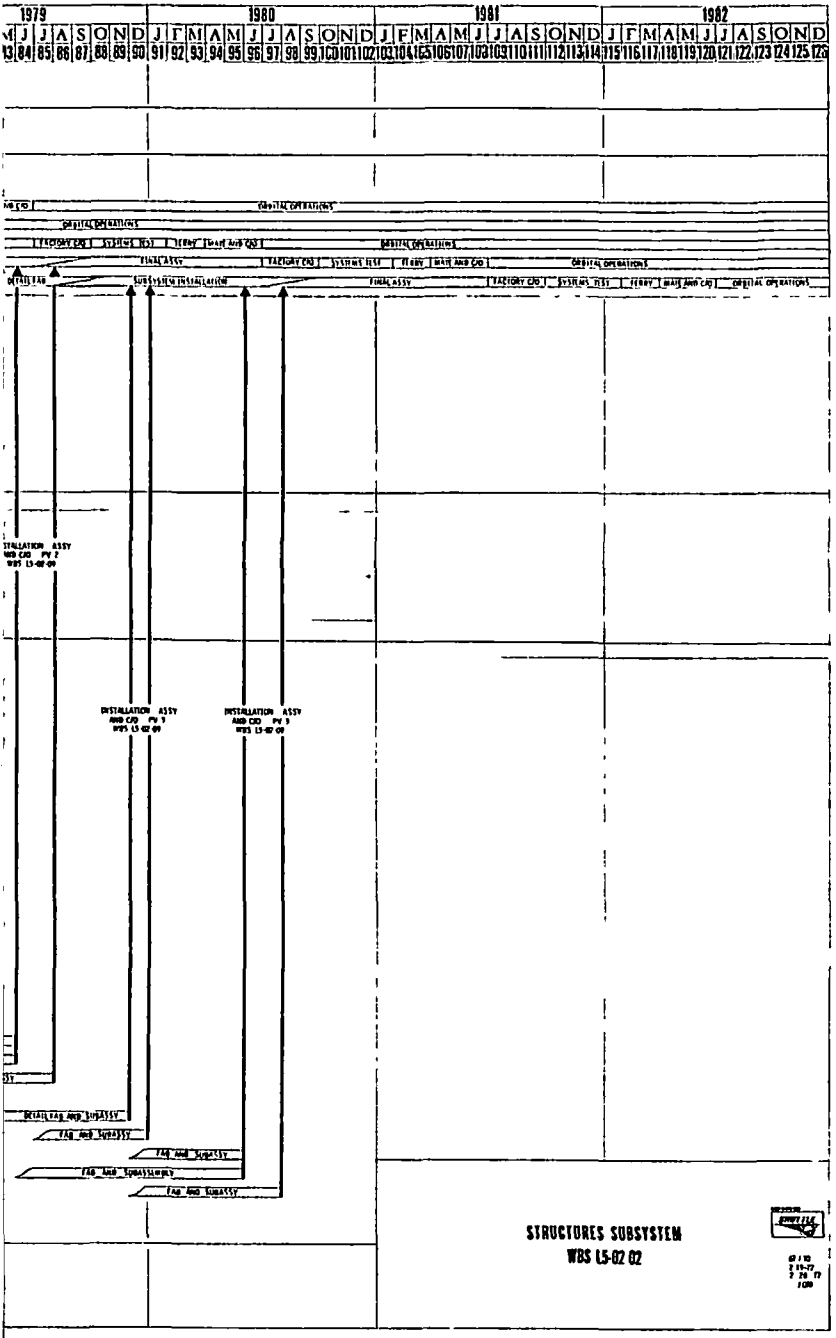

Fig. 5-1 Structures Subsystem

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5.2 ORBITER PROPULSION SUBSYSTEM (WBS Level 4, L5-02-03)

The orbiter propulsion system refers to the main propulsion system attitude control-propulsion system (ACPS/RCS) orbit maneuver propulsion system (OMS), and the airbreathing-engine propulsion system (ABES). These systems consist of the following major elements:

Main Propulsion System

- Main Engines (GFE)
- Propellant Delivery System – LO_2
- Propellant Delivery System – LH_2
- Pressurization and Venting
- Main Engine Interface

ACPS/RCS

- Propellant Storage
- Propellant Delivery System
- Pressurization and Venting
- Rocket Thruster Interface

OMS

- Propellant Storage
- Propellant Delivery System
- Pressurization and Venting
- Rocket Engine Interface

ABES

- Fuel Storage
- Fuel Delivery System
- Pressurization and Venting
- Turbojet Engine Interface

These subsystems include feedlines and valves, pressurization lines and valves, propellant gaging and utilization, regulators, sensors, venting systems, controls, and storage tanks.

The propulsion subsystem development schedule is depicted in Fig. 5-2.

This WBS element provides all engineering design, development, and analyses; tool design, fabrication, and maintenance; manufacturing of detail parts and components, assemblies, and subassemblies; quality control; inspection; and procurement activities

to provide propulsion elements for all modes of operation consisting of a main propulsion subsystem (MPS) with GFE engine, reaction control subsystem (ACPS/RCS) orbital maneuver propulsion subsystem (OMS), and an airbreathing propulsion subsystem (ABES). Included in the effort are the interface/integration activities with main engine manufacturer, design and fabrication of mockups, fabrication of spares and test articles, and repair of hardware.

5.2.1 Products and Services

The deliverable products of this effort are four complete orbital configuration propulsion subsystems ready for installation in Orbiter Vehicles FTV-2, PV-1, PV-2, and PV-3. A prototype propulsion subsystem will be produced with dummy rocket engines for installation in FTV-1 for horizontal flight test and will be retrofitted to orbital configuration later. All DRL-required specifications, procedures, test reports, and technical manuals will be supplied. Maintenance services will be provided as defined by the contract.

5.2.2 Schedule Rationale

Simultaneously with the Authority to Proceed (ATP), the Propulsion Subsystem design and development efforts will be initiated. Prior to the Orbiter Preliminary Requirements Review (PRR) at 90 days, preliminary design of all four elements – MPS, OMS, ACPS, and ABES – will be advanced to the point that all options are clearly defined. Design analyses and trade studies will be in process and general subsystem requirements will be nearing formalization. Preliminary discussions will be started with potential subcontractors. A plan for a comprehensive development test program of all appropriate propulsion subsystem elements will be presented at PRR. Material requests will accompany the plan, defining all critical components and material required to support the development test program. All pertinent propulsion subsystem data will be compiled and made available for the PRR.

The period ending at Orbiter System Requirements Review (SRR) will be devoted to a continuation of preliminary design and analyses of all subsystem elements. Coordination activities related to the main engine ICD will be progressing with the Customer

and engine Contractor. Configuration item Part I specifications will be formulated and development test unit (DTU) hardware fabrication will be started. Schedule-critical items will be procured, fabricated, or subcontracted as appropriate. Engineering mockups will be constructed as required. Preliminary contract negotiations will be conducted with all potential subcontractors for propulsion hardware. Technical data developed during this period will help shape a definitive configuration for each element of the propulsion subsystem and this material will be used in support of SRR.

A major design and development effort will be expended on the propulsion subsystem during the nine month period ending with Orbiter Preliminary Design Review. The subsystem preliminary design and the required CI Part I specifications will be completed. A subsystem PDR will be conducted as early in this period as possible but no later than one month prior to Orbiter PDR. Much of the detail design of the major elements and critical components will be completed. Fabrication of all development test items and selected qualification test hardware will be in process. Subcontracts will be negotiated for OMS and ACPS thrusters and the ABES engine. Near the end of the period manufacturing planning will be started for FTV-1 horizontal flight test propulsion subsystem. Fabrication of the MPS engine simulators for the structural test vehicle (STV) and FTV-1 will be in process. The FTV-1 will be refurbished subsequent to FMOF to orbital configuration. The design and development activities to this point will be reflected in the comprehensive, cost-effective technical requirements of the Part I specifications presented to the Customer for approval prior to PDR. The approval of these specifications will constitute the definition of the propulsion subsystem allocated baseline and will initiate configuration management to be accomplished at the individual configuration item level by control of the specified requirements for qualification and performance.

During the 15 months between Orbiter PDR and Critical Design Review (CDR), the propulsion subsystem engineering design, analyses, trade studies, development testing, and much of the qualification test program will be completed. A critical design review of the propulsion subsystem will be conducted at the end of 29 months into the program at which time the CI Part II specifications will be presented for approval. Customer approval of the specifications will define the subsystem product baseline and permit the conclusion of qualification testing. "Hot-fire" certification of the MPS engine will

occur at the end of 52 months. Early approval of the subsystem configuration is required to support installation into FTV-1 and FTV-2 in consonance with the vehicle schedules. The prototype subsystem for FTV-1, which includes a mass simulated MPS engine, will be completed and prepared for installation into the vehicle. The mass simulated MPS engine for STV will also be completed and prepared for installation. Following subsystem CDR, engineering will resolve all open items and release all required documentation for start of the FTV-2 propulsion manufacturing efforts. The propulsion development module (PDM) fabrication will be started at this time. The results of the propulsion subsystem engineering and testing to date will be used in support of the Orbiter CDR.

The horizontal flight test program is the next major milestone and is scheduled for 18 months after Orbit CDR. The test program will employ the FTV-1 with a prototype propulsion subsystem. The subsystem engineering group will provide sustaining and liaison engineering support of FTV-1 propulsion through final assembly, checkout, systems test, and ground test in preparation of first flight. They will also be supporting FTV-2 through subsystem installation and final assembly. Other significant test activities involving propulsion components and requiring support during this period include PDM through preliminary "hot-fire" and STV static-dynamic testing to 80 percent limit load. FTV-2 will initially be equipped with functional test rocket engines which will be replaced with fully qualified engines during the facility and GSE checkout activities and prior to the mater, and checkout leading to FMDF.

The horizontal flight test program will span a 19-month period and will be concluded approximately one month prior to the first manned orbital flight in March 1978. The propulsion subsystem group will be active with liaison engineering support of FTV-1 during the test span and in preparation of required engineering drawings, specifications, and procedures for retrofit to orbital configuration. Engineering, manufacturing, and test operations will also be performing the necessary propulsion subsystem functions for FTV-2 from factory checkout through mate with booster and checkout at the launch site. Manufacturing will be fabricating and assembling propulsion subsystem components for PV-1 in readiness for installation. The STV static-dynamic test program will have progressed to 100 percent limit load.

During the last phase of the program, the engineering, manufacturing, and test operations personnel will provide sustaining and liaison activities required in getting the propulsion subsystem installed, tested, and operational in all vehicles. Fabrication and assembly of the propulsion subsystems to a condition of ready to install in PV-2 and PV-3 will be accomplished early in this period. The retrofit of the propulsion subsystem in FTV-1 to orbital configuration will create the need for a large amount of liaison activities for this group. A continuing effort will be the maintenance of the operational propulsion subsystems as required.

5.2.3 Schedule Risk

The schedule risks associated with the propulsion subsystem are quite significant during the first two years of the program. The prototype subsystem components for FTV-1 are required for installation at approximately 20 months after ATP, which means completed hardware before CDR and therefore items built to prereleased designs and not qualified. This increases the magnitude of the retrofit effort. FTV-2 is a more serious problem because the propulsion subsystem is required a few months later, with development testing still in process and preliminary "hot-fire" more than 18 months downstream. FTV-2 is initially outfitted with functional test engines. If a major design or performance characteristic requires change as a result of the development test program, required changes to FTV-2 might impact start of orbital operations.

The availability of the propulsion test engines to support the PDM hot firing certification is an even more pacing element of the program. The main engine development program is the pacing element for the Space Shuttle Program.

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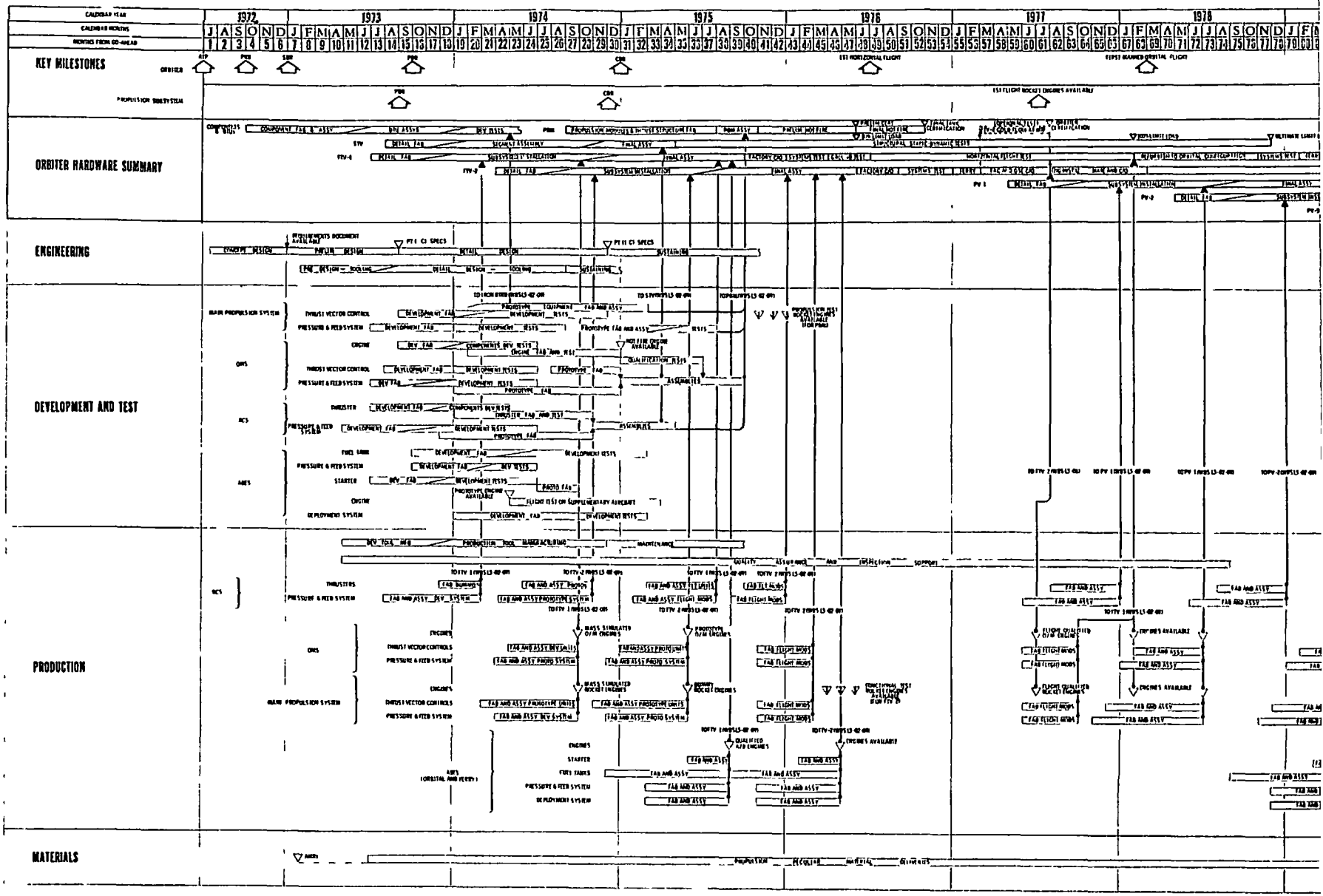
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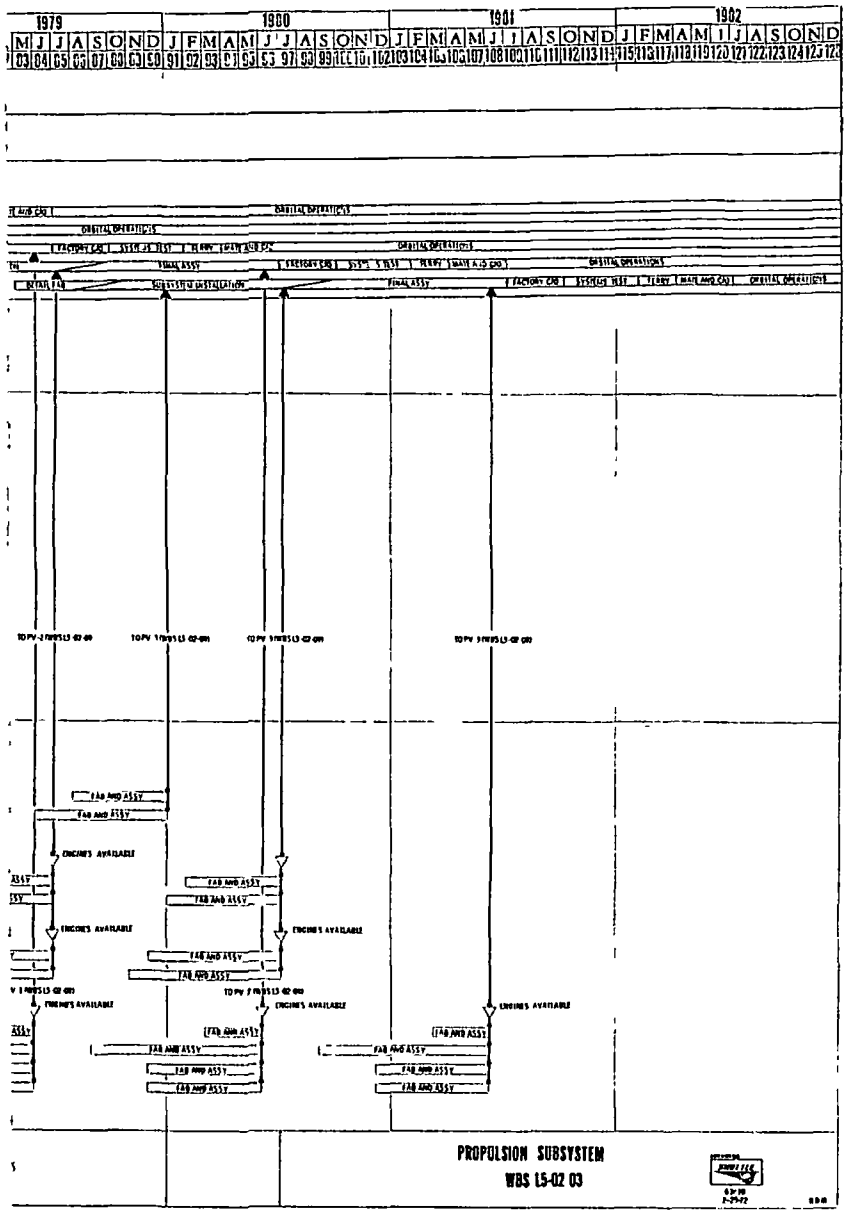

Fig. 5-2 Propulsion Subsystem

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5.3 ORBITER POWER SUBSYSTEM (WBS Level 4, L5-02-04)

The power system provides the electrical power and mechanical power for operation of the orbiter from activation prior to launch through orbital operations and orbiter landing following orbital missions or ferry flights. The system consists of the following major equipment items:

Electrical Power

- Fuel Cell Power Plants
  - Heat Transfer
  - Reactant Feed
  - Purge Control
  - Product Water
  - Reactant Storage
- Generators
- Batteries

Mechanical Power

- Hydraulic
- Pneumatic
- Distribution System
- Thermal Conditioning

Auxiliary Power Units (APU)

- Heat Rejection
- Reactant Feed
- AC Generator
- Thermal Conditioning

Figure 5-3 displays the spans and tasks required for the development of the Power Subsystem.

The Power Subsystem WBS element provides all engineering design, development, test, and analyses; tool design, fabrication and maintenance; manufacturing of detail parts and components, assemblies, and subassemblies; quality control; inspection; and procurement activities required to provide a totally integrated power generation system consisting of electrical, hydraulic, and turbine power subsystems. All test and support articles, design and fabrication of the mockups, fabrication of all spares and repair of hardware are included in this task.

5.3.1 Products and Services

The deliverable products of this effort are four complete orbital configuration power subsystems installed in Orbiter Vehicles FTV-2, PV-1, PV-2, and PV-3. An additional prototype power subsystem will be installed in FTV-1 for horizontal flight and will be refurbished to orbital configuration later. All DRL-required specifications, procedures, test reports, and technical manuals will be supplied. Maintenance services will be provided as defined by the contract.

5.3.2 Schedule Rationale

Design and development efforts on the Power Subsystem will be initiated at Authority to Proceed (ATP) with special attention being given to the design and development testing of the fuel cells. Prior to the Orbiter Preliminary Requirements Review (PRR) at 90 days, the power subsystem preliminary design will be well advanced; Configuration Item Part I specifications for the hydraulic actuator, auxiliary power unit (APU), fuel cells, and the a-c generator will be started; and material requests for the procurement of long-lead time items, i.e., pump bellows, will be prepared for Customer approval. All pertinent power subsystem data will be compiled and made available for the PRR.

The next 90-day span, ending with the Orbiter System Requirements Review (SRR), will encompass many of the same tasks initiated prior to PRR plus the addition of others. Power subsystem preliminary design activities will be continued, major elements of hardware and critical item components design will be started, design analyses and studies will be a major engineering activity while manufacturing is planning the fabrication of development test units and the test group is writing the test procedures and preparing the test set-ups. Preliminary contract negotiations will be entered into with all potential subcontractors of the fuel cells. By the end of this period, schedule-critical items will be arriving at the LMSC dock. Accrued data on this subsystem will be used in support of the SRR. Engineering mockups will be started as required.

The next nine-month period, ending with the Orbiter Preliminary Design Review (PDR), encompasses a major design and development effort on the power subsystem.

The subsystem preliminary design and the required Configuration Item Part I specifications will be complete. Much of the detail design of the subsystem, major items, and other components will be completed. Fabrication of all development test items and selected qualification test hardware will be in process. A subcontract will be negotiated for the a-c generator. Development testing will have been started on the APU, hydraulic actuator, fuel cell, generator, and the bellows pump. Fabrication will be started on a prototype power subsystem to be installed in FTV-1 for use during horizontal flight test program. The power subsystem to be employed in FTV-1 will not utilize fuel cells for the horizontal flight test configuration but will be refurbished later to support orbital operations. The design and development activities to this point will be reflected in the comprehensive, cost-effective technical requirements of the Part I specifications presented to the Customer for approval prior to PDR. The approval of these specifications will constitute the definition of the power subsystem allocated baseline and initiation of configuration management accomplished at the individual configuration item level by control of the requirements for its performance and qualification as stated.

The 15 months between Orbiter PDR and Critical Design Review (CDR) will see the power subsystem engineering design, studies, analyses, development testing, and qualification test programs completed. A critical design review of the power subsystem will be conducted 20 months into the program, at which time the CI Part II specifications will be presented for approval. Customer approval of the specifications will define the subsystem product baseline and permit the conclusion of qualification testing. Early approval of the subsystem configuration is required to support installation into FTV-1 and FTV-2 in accordance with the vehicle schedules. The electrical power distribution, conditioning, and control elements are part of the Avionics Subsystem. All hydraulic plumbing will be fabricated, checked to a mock-up, and installed in the vehicle during the subsystem installation and final assembly periods. In addition to the fuel cell qualification program, another fuel cell will be fabricated for testing to demonstrate the capability for an operating life of 5000 hours. The prototype power subsystem, consisting of special batteries to replace the fuel cells, three a-c generators, and all mechanical power units, will be completed and delivered to FTV-1

for installation. Following power subsystem CDR, engineering will resolve all open items and gradually reduce the staff to that required for manufacturing, systems test, and operations support to conclusion of the program. Engineering will prepare for and support all required activities associated with Orbiter CDR.

The next major milestone, 18 months after Orbiter CDR, is start of the horizontal flight test program utilizing FTV-1 with the prototype power subsystem. The power subsystem engineering group will be actively supporting FTV-1 through final assembly, checkout, systems test, and ground test in preparation for first flight. They will also be supporting FTV-2 through subsystem installation and final assembly. The schedule indicates that all manufacturing activities, related to major component fabrication, will be completed except those associated with the fuel cells. An alternate schedule consideration is the delay of approximately three years in starting the mechanical power units and a-c generators for PV-1, PV-2 and PV-3. The alternate schedule possibilities require a cost-effectiveness analysis of the benefits of continuous production and long-time controlled storage vs the incremental funding available and two fabrication periods with minimum storage.

The horizontal flight test program spans a 19-month period and is concluded approximately one month prior to the first manned orbital flight in March 1978. The engineering group will be very active in support of FTV-1 during the test span and in preparation of required engineering drawings, specifications, and procedures for refurbishment to orbital configuration. Engineering will also be performing the necessary power subsystem functions for FTV-2 from factory checkout through mate with booster and checkout at the launch site. There will be minimal engineering activity on PV-1 at this time.

Following the first operational flight in FTV-2, there will be almost five years of orbit operations flights utilizing FTV-2, PV-1, PV-2, PV-3, and a refurbished FTV-1. During this period, from March 1978 to end of the program, the engineering, manufacturing, and test personnel will be concerned with getting the power subsystem installed, tested, and operational in all vehicles. A significant effort will be associated with the refurbishment of the subsystem in FTV-1. Other major activities during this phase of the program will be maintenance of the power subsystem as required.

5.3.3 Schedule Risk

The schedule risks associated with the power subsystem are relatively minor but a few selected items will require special attention. The hydraulic pump bellows and the a-c generator development programs could impact FTV-1 operations. The single most significant item for potential impact on the FTV-2 orbital operations is the development of fuel cells required for installation at 36 months after ATP.

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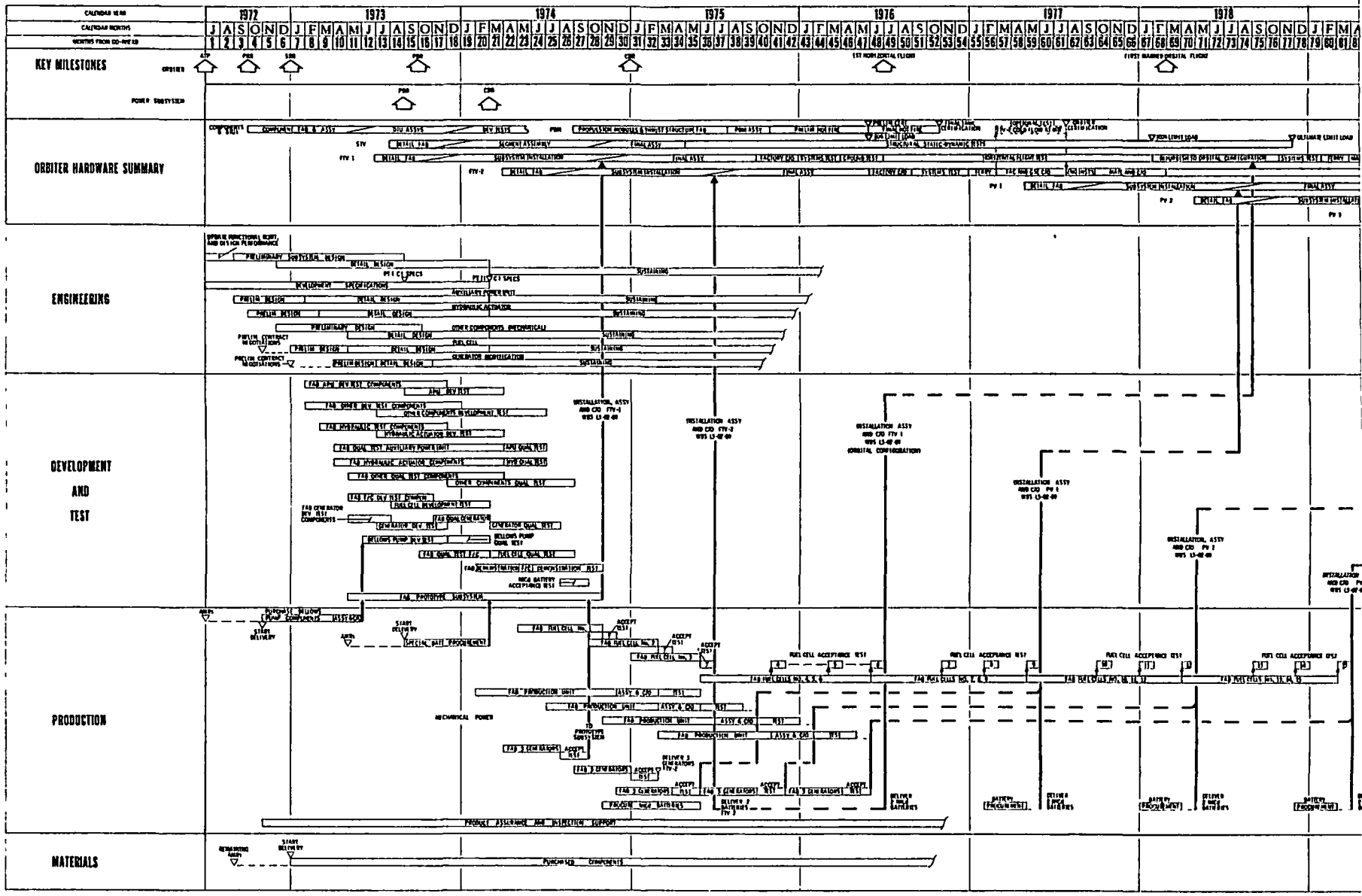
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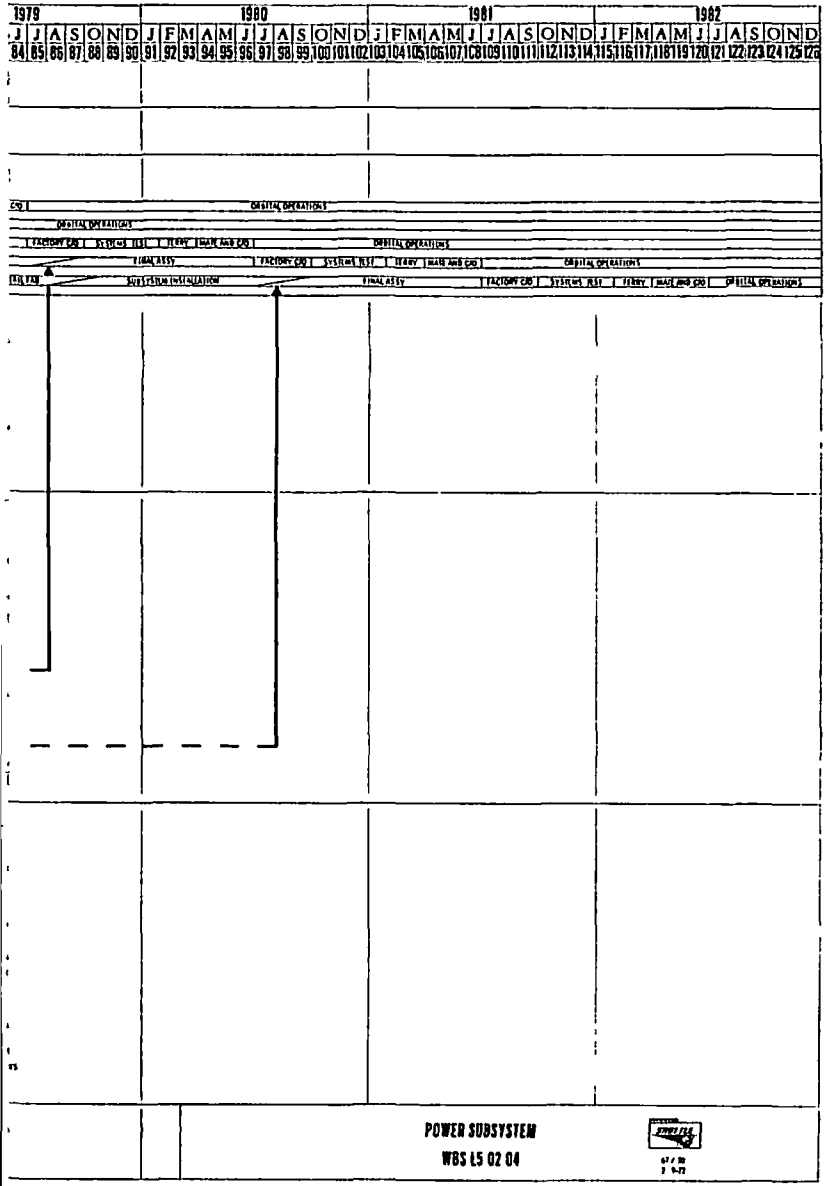

Fig. 5-3 Power Subsystem

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5.4 ORBITER AVIONICS SUBSYSTEM (WBS Level 4, L5-02-05)

The orbiter Avionics Subsystem consists of the following subsystems and major equipment elements:

Guidance, Navigation and Control

- Inertial Reference Unit
- Digital Computer
- Star Tracker
- Horizon Sensor
- Orbit Altimeter
- Rendezvous and Landing DME (PRS)
- Main Engine Gimbal Servo Actuator
- TVC Electronics
- ACPS Electronics

Communications and Tracking

- Antennas
- Update Data Link
- S-Band Equipment – power amplifier, unified S-band equipment
- UHF Transceivers
- Signal Processors
- Audio Center Equipment
- Antenna Switches

Data Management

- Computer
- Data Transmission Lines
- System Interface Units (SIU)
- Analog Multiplex Data Gathering Subsystem
- Imput/Output Interface and Controller Units

Displays and Controls

- Flight Controls – attitude, translation, etc.
- Multifunction Display Units (MDU)
- Main Instrument Panel
- General Displays
- Control and Display Test and Checkout
- Hand Controllers
- Keyboards

Instrumentation

- Transducing Equipment
- Signal Conditioning Equipment
- Multiplexing Equipment
- Telemetry Formatting Controls
- FM Recording Equipment
- Flight Data Recorder
- Time Code Generator

Electrical Power Distribution

- Transformers – Rectifiers
- AC Generator Control Unit (GCU)
- Power Cabling
- Power Switching
- Inverter Modules
- Power Distribution Buses
- Power Converter Modules
- Inverter Control
- Battery Chargers
- Power Controllers

Software

- Executive Software
- Applications Software
- Support Software

Figure 5-4 is the avionics subsystem activity schedule.

The avionics subsystem WBS element includes all engineering design, development and analysis; software; tool design, fabrication and maintenance; manufacturing of detail parts and components, assemblies, and subassemblies; certification testing; quality control; inspection; and procurement activities required to provide an avionics system for the Orbiter Vehicle that will provide the functions of guidance and control, navigation, communications, data management, displays and controls, instrumentation (flight test and operational), and electrical power distribution and control. This element also includes test articles, design and fabrication of the mockups, fabrication of spares and repair of hardware, and the design and fabrication of the test and support equipment.

5.4.1 Products and Services

The deliverable products of this WBS element will consist of four complete orbital configuration avionics subsystems ready for installation in Orbiter Vehicles FTV-2, PV-1, PV-2, and PV-3. In addition, a prototype avionics subsystem will be produced for installation in FTV-1 for horizontal flight and will be retrofitted to orbital configuration later. All DRL required specifications, procedures, test reports, and technical manuals will be supplied. Maintenance services will be provided as defined by the contract.

5.4.2 Schedule Rationale

The Avionics Subsystem design and development efforts will be initiated at receipt of Authority To Proceed (ATP). During the following 90 days prior to the Orbiter Preliminary Requirements Review (PRR), the preliminary design of the major elements of the subsystem will be underway and a preliminary definition of the various interfaces will be established. Design analyses and trade studies will be in process and general subsystem requirements will be nearing formalization. Contacts with potential suppliers and subcontractors will be made. Verification of preliminary subsystem requirements will be presented in a plan for a comprehensive development test program of all appropriate avionics subsystem elements at PRR. Material Requests will accompany the plan defining all schedule-critical components and material required to support the development test program. All pertinent avionics subsystem data will be compiled and made available for support of PRR.

The period ending at Orbiter System Requirements Review (SRR) will be devoted to a continuation of preliminary design and analyses of all subsystem elements. Coordination activities related to the avionics ICD will be progressing with the Customer and Associate Contractors. Configuration Item Part I specifications will be formulated and engineering development test unit (DTU) hardware fabrication will be started. Schedule-critical items will be procured, fabricated, or subcontracted as appropriate. Engineering mockups will be constructed as required. Preliminary contract negotiations will be conducted with all potential subcontractors for avionics hardware. Technical data developed during this period will help shape a definitive configuration for each element of

the avionics subsystem and this material will be used in support of SRR. By reference only, provisions for an Avionics Systems Integration Lab (SIL) for subsystem development test gets underway at the start of this period in order to be ready by May 1973.

A major design and development effort will be expended on the avionics subsystem during the nine months ending with Orbiter Preliminary Design Review. The subsystem preliminary design and the required CI Part I specifications will be completed. A subsystem PDR will be conducted approximately one month prior to Orbiter PDR. Much of the detail design of the major elements and critical components will be completed. Fabrication of all development test items and selected qualification test hardware will be in process and tool design will be started. Included within this manufacturing effort are the form and fit units as well as wire harnesses. Additionally, development test support for systems is provided and available for use by November 1973. The design and development activities to this point will be reflected in the comprehensive, cost-effective technical requirements of the Part I specifications presented to the Customer for approval prior to PDR. The approval of these specifications will constitute the definition of the avionics subsystem allocated baseline and will initiate configuration management to be accomplished at the individual configuration item level by control of the specified requirements for qualification and performance.

During the 15 months between Orbiter PDR and Critical Design Review (CDR), the avionics subsystem engineering design, analyses, trade studies, development testing, tool design, and qualification testing of the Horizontal Flight Avionics Equipment will be completed. With subsystem and system developments testing having been completed, the Avionics Systems Integration Lab (SIL) will require refurbishment to meet production testing. A critical design review of the Avionics subsystem will be conducted at the end of the 29th month, at which time the CI Part II specifications will be presented for approval. Customer approval of the specifications will define the subsystem product baseline and permit the conclusion of qualification testing. Early approval of the subsystem configuration is required to support installation into FTV-1 and FTV-2 in accordance with the vehicle schedules. The prototype avionics subsystem, to be used during horizontal flight test of FTV-1, will be started prior to CDR as a means of supporting these schedules. Following avionics subystem CDR, engineering will

resolve all open items and release all required documentation for start of the FTV-2 avionics manufacturing efforts. The results of the avionics subsystem engineering and testing to date will be used in support of the Orbiter CDR.

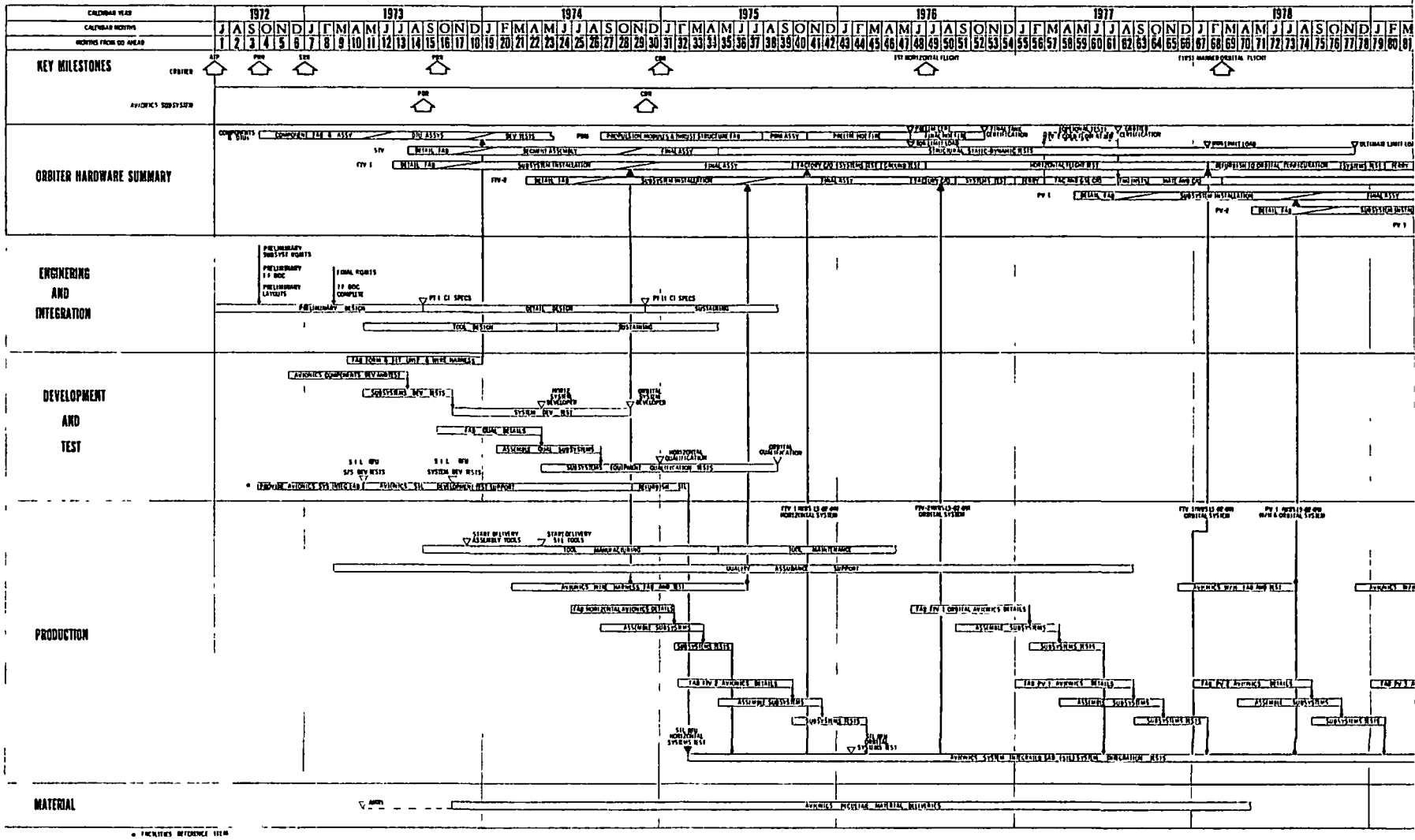
The start of the horizontal flight test is the next major milestone scheduled for 18 months after Orbiter CDR. This period encompasses completion of qualification testting, completion of tool fabrication, completion of the avionics subsystem assembly, and all testing in preparation for installation into FTV-1. Fabrication of wire harnesses and components, assembly and most of the testing for the FTV-2 orbital configuration subsystem will be accomplished. Sustaining and liaison engineering support of FTV-1 avionics subsystem will be provided through final assembly, checkout, systems test and ground test in preparation for first flight. This same support will be provided for installation of wire harnesses and fit-check equipment for FTV-2.

The horizontal flight test program will span a 19-month period and will be concluded approximately one month prior to the first manned orbital flight in March 1978. The avionics subsystem personnel will be active with liaison engineering support of FTV-1 during the test span and in preparation of required engineering drawings, specifications, and procedures for retrofit to orbital configuration. Engineering, manufacturing, and test operations will also be performing the necessary avionics subsystem functions for FTV-2 from factory checkout through mate with booster and checkout at the launch site. The avionics equipment used for final assembly, factory checkout, and the initial phases of systems test will be the qualification test hardware. The fully qualified components, which have been through the avionics system integration lab, will be retrofitted into the vehicle during the final phases of the FTV-2 factory checkout operations. The manufacturing, assembly, and testing of the FTV-1 orbital configuration avionics subsystem for retrofit into the vehicle will be completed. The PV-1 avionics will be manufactured and assembled during this span. During the last phase of the program, the engineering, manufacturing and test operations personnel will provide sustaining engineering and liaison activities required to retrofit FTV-1 with an orbital configuration avionics subsystem, systems test, ferry operations, mate and checkout at the launch site, and orbital operations. Similar activities will be required to support the fabrication, assembly, test, and preparation for installation of the avionics subsystems into PV-1, PV-2, and PV-3. Subsystem support is also required for each vehicle from final

assembly to orbit operations. A continuing effort will be the maintenance of the operational avionics subsystems as required.

5.4.3 Schedule Risk

The schedule risks associated with the Avionics Subsystem will plague the program continuously during the first four years. The horizontal configuration subsystem for FTV-1 will be nearly fabricated and halfway through assembly before qualification tests are complete. A similar condition exists for the first orbital configuration subsystem for use on FTV-2. Another problem with the subsystem for FTV-2 is that it should be installed prior to systems test operations rather than near the conclusion of systems test as now planned. If a significant change/modification should become mandatory as a result of systems test operations on FTV-1, the reaction time to incorporate into FTV-2 without impacting start of orbital operations is very limited.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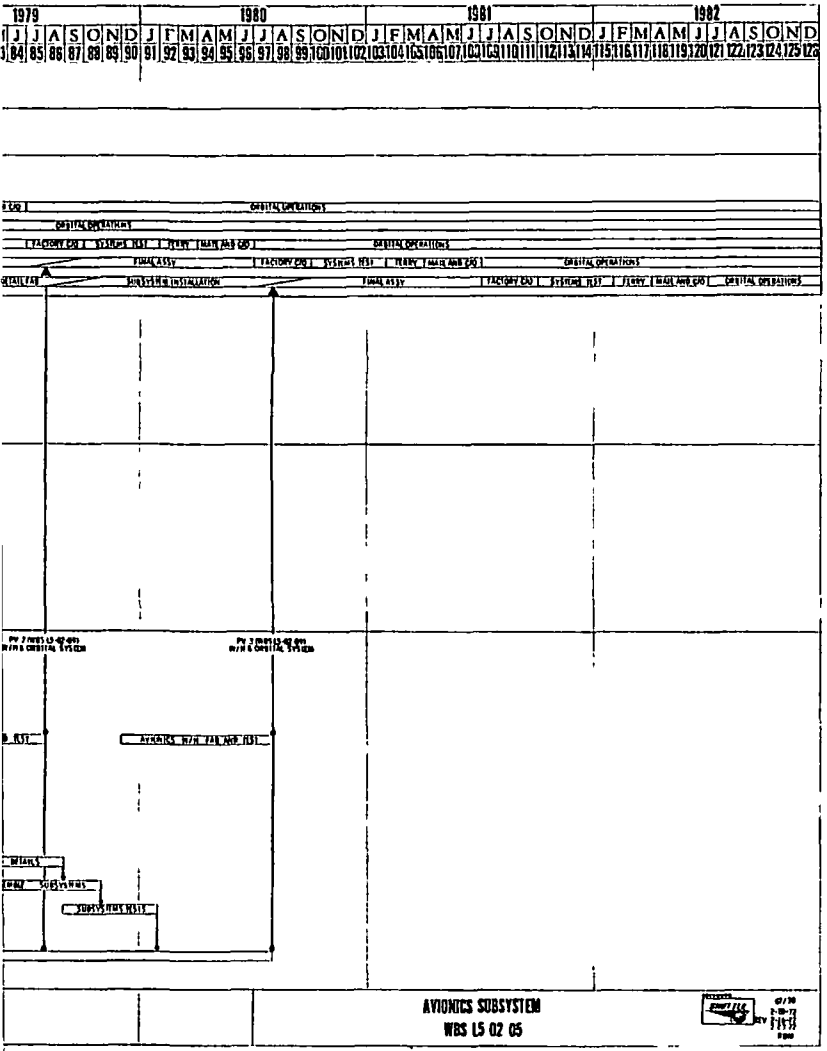

Fig. 5-4 Avionics Subsystem

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5.5 ORBITER ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM (EC/LSS) (WBS Level 4, L5-02-06)

The Environmental Control and Life Support System provides control of the environment of the crew compartment through the atmosphere revitalization subsystem, thermal control for the crew and for equipment located in the crew compartment, waste management, emergency breathing provisions, water for sublimation, food and water for personnel consumption, and extravehicular/intravehicular activity accommodations. Figure 5-5 is the schedule for the development of the EC/LSS subsystem.

The Environmental Control/Life Support Subsystem WBS element includes all engineering design, development, and analyses; tool design, fabrication and maintenance; manufacturing of detail parts and components, assemblies and subassemblies; quality control, inspection; and procurement activities required to provide the life support for the flight personnel and environmental control for the Orbiter Vehicle during all mission phases. This element also includes all test and support articles, design and fabrication of the mockups, fabrication of all spares and repair of hardware.

5.5.1 Products and Services

The deliverable products of this WBS element will consist of four complete orbital configuration environmental control/life support subsystems (EC/LSS) ready for installation in Orbiter Vehicles FTV-2, PV-1, PV-2, and PV-3; plus a prototype EC/LSS which will be produced for installation in FTV-1 for horizontal flight test and retrofitted to orbital configuration later. All DRL-required specifications, procedures, test reports and technical manuals will be supplied. Spares and repair services will be provided as negotiated in the contract.

5.5.2 Schedule Rationale

The EC/LSS design and development efforts will be initiated at receipt of Authority To Proceed (ATP). During the following 90 days prior to the Orbiter Preliminary Requirments Review (PRR), the preliminary design layout of the major elements of the subsystem will be underway and a preliminary definition of the EC/LSS interfaces

will be established. Design analyses and trade studies will be in process and general subsystem requirements will be nearing formalization. Preliminary contract negotiations will be conducted with all potential subcontractors for EC/LSS hardware. A comprehensive development test program plan for verification of preliminary EC/LSS requirements of all appropriate subsystem elements will be presented at PRR. Selected material requests will accompany the plan defining all schedule-critical components and material required to support the development test program. All pertinent EC/LSS data will be compiled and made available for support of PRR.

The period ending at Orbiter System Requirements Review (SRR) will be devoted to a continuation of preliminary design and analyses of all subsystem elements. Coordination activities related to the EC/LSS ICD will be progressing with the Customer and Associate Contractors. Configuration Item Part I specifications will be formulated and development test unit (DTU) hardware fabrication will be started. Schedule-critical items will be procured, fabricated or subcontracted as appropriate. Engineering mockups will be constructed as required. Technical data developed during this period will help shape a definitive configuration for each element of the EC/LSS and this material will be used in support of SRR.

A major design and development effort will be expended on the EC/LSS during the next nine months that end with Orbiter Preliminary Design Review. The subsystem preliminary design and the required CI Part I specifications will be completed. A subsystem PDR will be conducted approximately three (3) months prior to Orbiter PDR. Much of the detail design of the major elements and critical components will be completed. Fabrication of all development test items and selected qualification test hardware will be in process and tool design will be started. The design and development activities to this point will be reflected in the comprehensive, cost-effective technical requirements of the Part I specifications presented to the Customer for approval prior to PDR. The approval of these specifications will constitute the definition of the EC/LSS allocated baseline and will initiate configuration management for accomplishment at the individual configuration item level by control of the specified requirements for qualification and performance.

During the 15 months between Orbiter PDR and Critical Design Review (CDR), the EC/LSS engineering design, analyses, trade studies, development testing, tool design, and much of the qualification test program will be completed. A critical design review of the EC/LSS will be conducted at the end of 28 months into the program at which time the CI Part II specifications will be presented for approval. Customer approval of the specifications will define the subsystem product baseline and permit the conclusion of qualification testing. Early approval of the EC/LSS configuration will be required to support installation into FTV-1 and FTV-2 in accordance with the vehicle schedules. The prototype EC/LSS, to be used during the horizontal flight test of FTV-1, fabrication will be started prior to PDR as a means of supporting the proposed schedule. The prototype EC/LSS components will be completed in manufacturing; the subsystem will be assembled, subsystem level testing will be accomplished, and the EC/LSS will be delivered to the FTV-1 vehicle ready for installation. Following EC/LSS PDR, engineering will resolve all open items and release documentation required for start of FTV-2 EC/LSS manufacturing efforts. The results of all studies, analyses, and tests to date will be used in support of the Orbiter CDR.

The start of the horizontal flight test is the next major milestone and is scheduled for eighteen months after Orbiter CDR. This period encompasses completion of qualification testing, completion of tool fabrication, and continuing sustaining and liaison engineering support. The subsystem for FTV-2 will also be completed and delivered to the vehicle ready for installation during this period. Sustaining and liaison engineering support will be provided to FTV-1 through the final assembly, checkout, systems test, and ground test in preparation of first flight. The same support will be provided to FTV-2 through EC/LSS installation and final assembly.

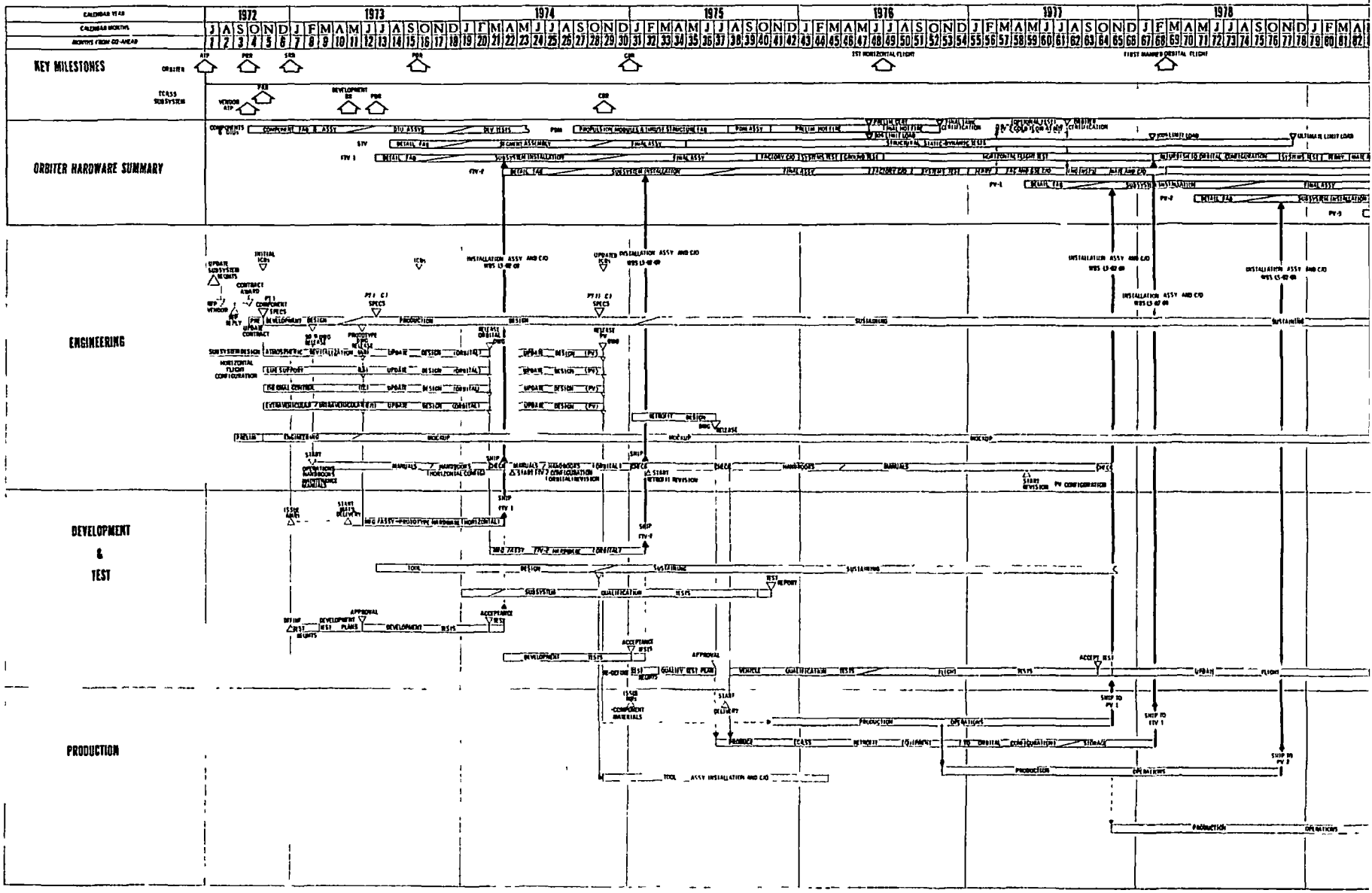
The horizontal flight test program will span a 19-month period and will be concluded approximately one month prior to the first manned orbital flight in March 1978. The EC/LSS group will be active with liaison engineering support of FTV-1 during the test span and in preparation of required engineering drawings, specifications, and procedures for retrofit of the EC/LSS to Orbital configuration. Engineering, manufacturing, and test operations will also be performing the necessary functions for FTV-2 EC/LSS

from factory checkout through mate with booster and checkout at the launch site. Manufacturing will be fabricating and assembling EC/LSS components for PV-1 in readiness for installation.

During the last phase of the program, the engineering, manufacturing, and test operations personnel will provide sustaining and liaison activities required in support of EC/LSS installation, testing, and operations in all vehicles. Fabrication, assembly and test of the EC/LSS to a condition of ready to install in PV-2 and PV-3 will be accomplished early in this period. The retrofit of the EC/LSS in FTV-1 to orbital configuration will be a major engineering, manufacturing, and test activity during this period. A continuing effort will be the maintenance of the operational EC/LSS as required.

5.5.3 Schedule Risk

The schedule risks associated with the EC/LSS involve FTV-1 and FTV-2 hardware. The horizontal flight configuration subsystem for FTV-1 will be fabricated and assembled before the qualification test program is complete and will significantly increase the amount of retrofit required for orbital flight. The problem is more serious for FTV-2 because this EC/LSS will also be fabricated before the qualification testing is complete and no retrofit program is planned.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DEVELOPMENT & TEST
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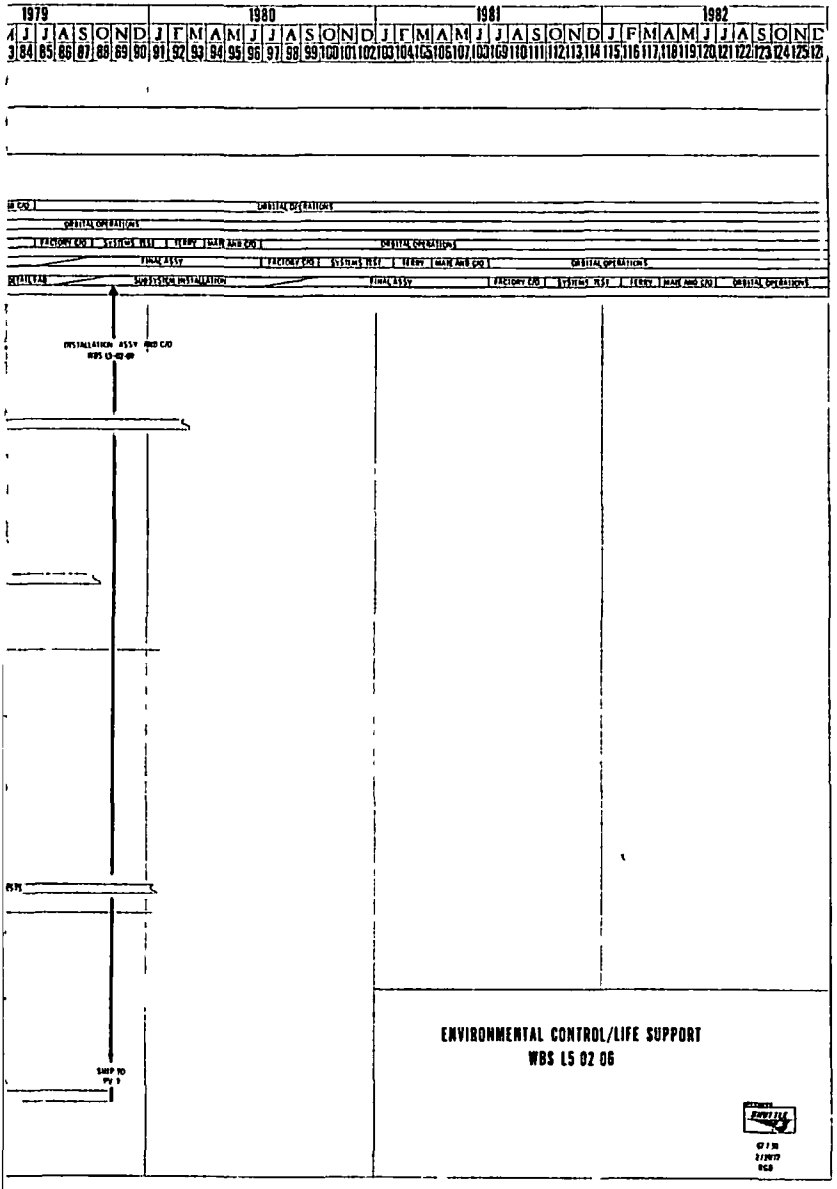

Fig 5-5 Environmental Control/Life Support Systems

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5.6 ORBITER CREW COMPARTMENT SUBSYSTEM (WBS Level 4, L5-02-07)

The Crew Compartment Subsystem makes provisions for crew accommodations for flight station concepts, crew visibility, habitability, the airlock, crew cabin configuration and avionics packaging in the pressurized crew compartment capsule. The development schedule for the Crew Compartment Subsystem is shown in Fig. 5-6.

The Crew Compartment Subsystem WBS element includes all effort to establish the display and control panel arrangements, display requirements and location in the crew compartment, and accommodations for the crew to perform cargo handling. The work effort includes all engineering design, development, and analysis; tool design, fabrication, and maintenance; manufacturing of detail parts and components, assemblies, and subassemblies; quality control; inspection; and procurement activities to provide the lower level WBS elements covering furnishings and equipment for the crew. The Crew Station furnishings and equipment will be complete and ready for installation and integration on the Orbiter Vehicle cabin. This effort also includes all test and support articles, design and fabrication of all spares and repair of hardware.

5.6.1 Products and Services

There will be a limited amount of hardware supplied under this WBS element. Most of the output is related to mission, system, and physiological requirements imposed on other subsystems for cabin arrangement and crew provisions and accommodations.

5.6.2 Schedule Rationale

The concepts and development of specifications will be started at ATP and continue through Program Requirements Review (PRR). At this time, the preliminary subsystem requirements, layouts and interface control documents will be reviewed. Preliminary subsystem design is started and GSE design requirements are clarified. Two months following PRR, the fabrication of development details will begin. At Orbiter System Requirements Review (SRR) the preliminary concepts and subsystem requirement will be confirmed with the Customer and the details and equipments of the subsystem will be proofed using the engineering mockup.

One month following SRR (Orbiter), the final requirements and the Interface Control Documents shall be firm and GSE design can be initiated. Fabrication of the Crew Compartment Details, the docking mechanism control and airlock details is begun.

By 1 March 1973, the Customer will start a review of development specifications; production tool design and GSE manufacturing will begin and fabrication of the crew compartment internal equipment will start. One month later, fabrication of ejection seats will begin and other details will be fabricated or procured.

Fabrication of details and equipments for the FTV-1 may begin on 1 May 1973, as shown in the schedule. A sequence of production operations is set for FTV-1, FTV-2, and the three production vehicles. By 1 June 1973, the CI Part I specifications are released and all development detail design is well defined. Effort continues on the details and equipment until August, when prototype assembly and qualification tests shall begin.

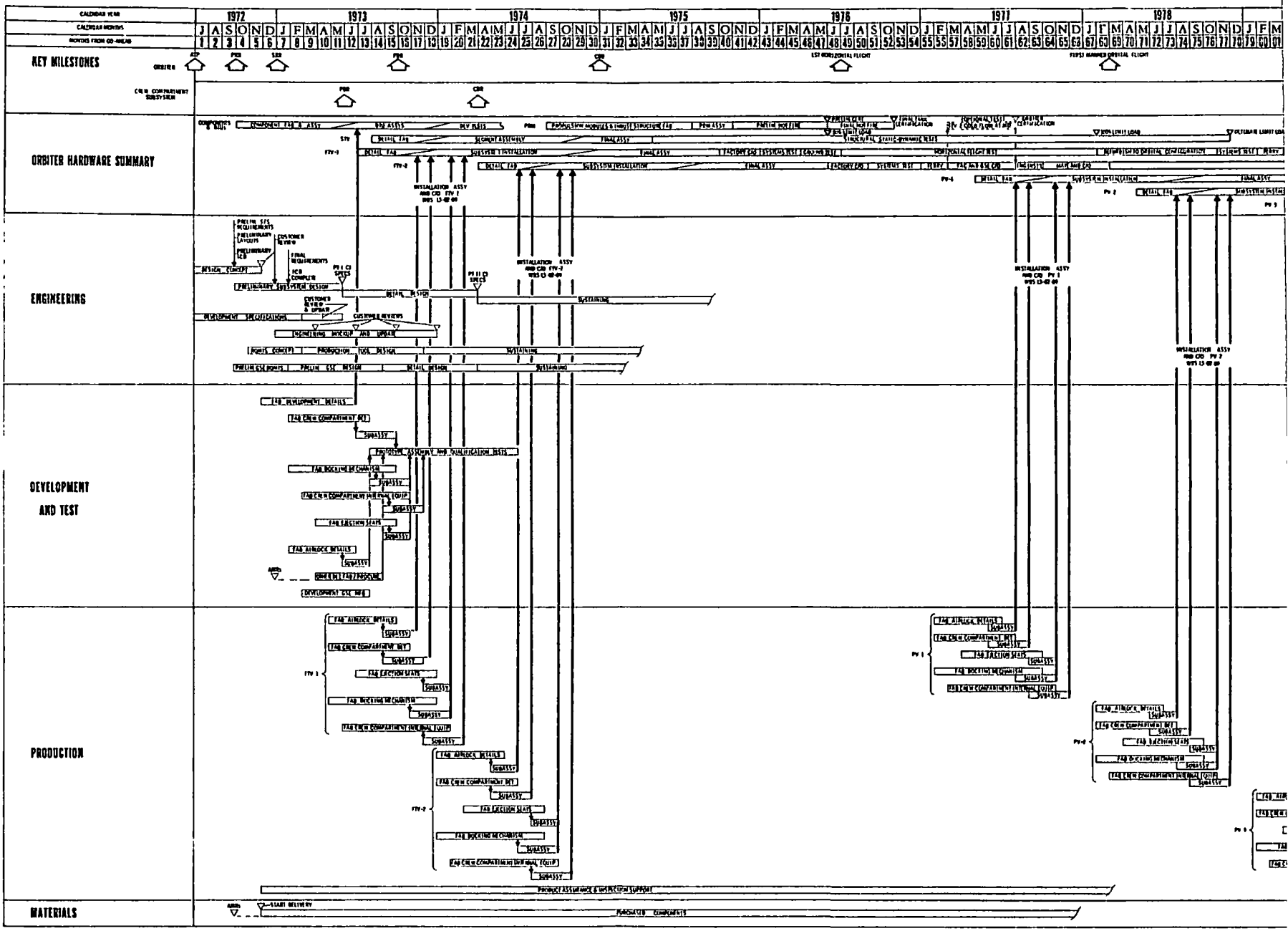
The subsystem CDR will be held on 1 April 1974, following installation of subassemblies into FTV-1. Detail Design is complete and CI Part I specifications are released. Sustaining design for the subsystem and GSE will continue through subsystem installation on FTV-2.

Fabrication of the crew compartment details and equipment will be curtailed until February of 1977 in anticipation of subsystem installation on PV-1, PV-2, and PV-3.

5.6.3 Schedule Risks

The greatest risk is in attempting to meet the FTV-1 and FTV-2 subsystem installation requirements without having flown the subsystem. The prototype qualifications test may be able to proof the subsystem to a simulated flight.

A second risk is a potential loss of fabrication and assembly capability from the end of subsystem installation on FTV-2 to the start of similar effort for PV-1, a period of 27 months.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MONTHS FROM GO-AHEAD
KEY MILESTONES
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CREW COMPARTMENT SUBSYSTEM
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FIRST MANNED ORBITAL FLIGHT

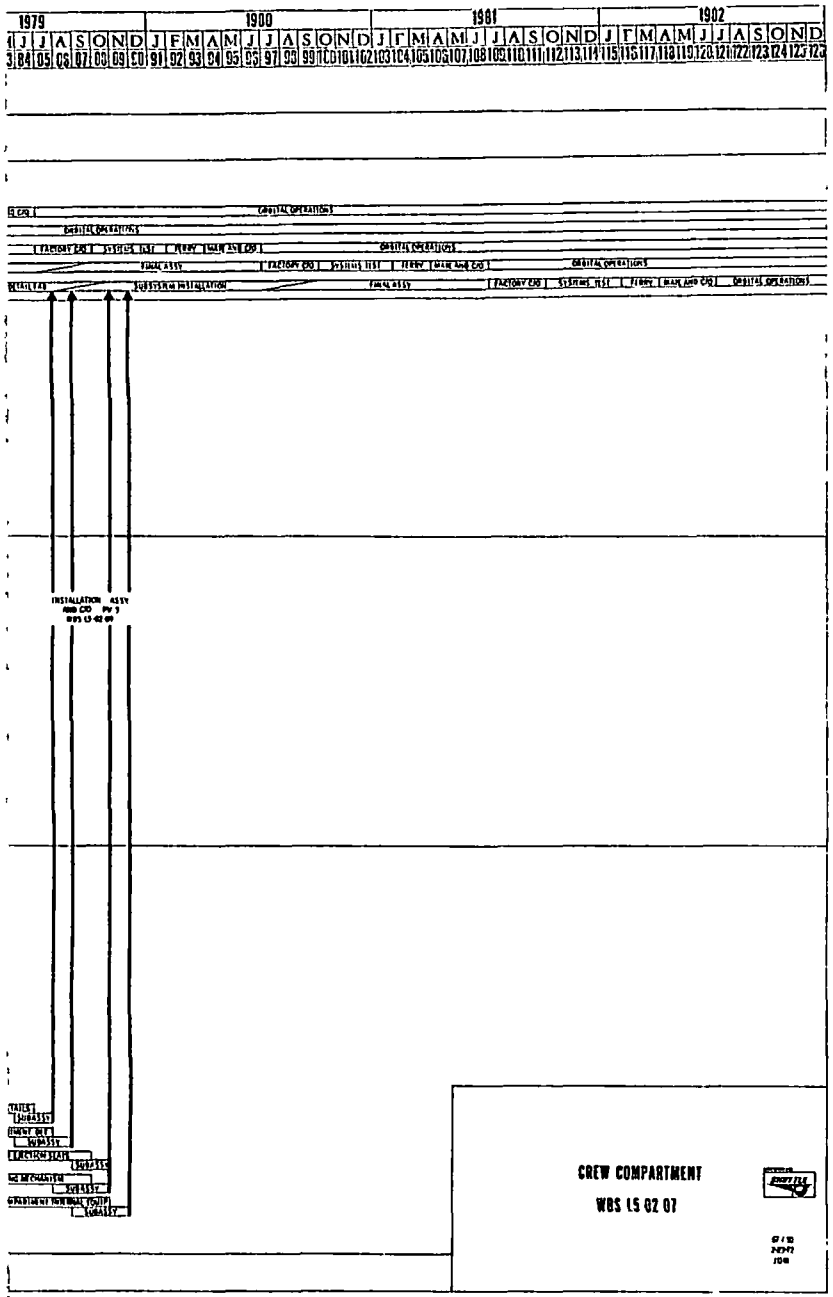

Fig. 5-6 Crew Compartment

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5.7 ORBITER INSTALLATION, ASSEMBLY, AND CHECKOUT (WBS Level 4, L5-02-09)

This schedule, Fig. 5-7, depicts the orbiter subsystems installation, final assembly, and checkout. Product support is included to illustrate the total support to the manufacturing assembly effort.

The orbital installation, assembly, and checkout WBS element refers to those activities and materials required to tool, manufacture, and checkout the Orbiter Vehicle and major test articles. It includes the activities necessary to furnish and activate manufacturing facilities; fabricate parts; install subsystems and GFE items; assemble the vehicles; production planning; tooling planning, design, fabrication, procurement and maintenance; quality control; and the work effort and materials required to perform in-process verification testing of the Orbiter Vehicle as it is being built and inspected and integrated vehicle checkout after final assembly. This element also includes packaging and shipping.

5.7.1 Products and Services

The services associated with this WBS element are identified above and are applicable to the five Orbiter Vehicles and the following major test articles; structural test vehicle (STV), propulsion development module (PDM), development test vehicle (DTV), and the "ironbird." No deliverable products are produced under this WBS element.

5.7.2 Schedule Rationale

The following discussion of the schedule is keyed to key milestones. Reference is made to installation of subsystems by WBS number. Referral back to the respective subsystem schedules will show the detail fabrication and subassembly spans.

Sept 1973 The first milestone to affect the function is the Preliminary Design Review (PDR). Detail Fabrication has started on the STV, DTV, Ironbird, and FTV-1. Preliminary Design is complete, and 10 percent

of the Detail Design drawings have been released. Production Planning has reached a point where Subassembly Log Books may be started as Assembly Peculiar Material Deliveries are received by Lockheed. Tool Design drawings are 20 percent released and Tools are being delivered to the Assembly Facility. The detail fabrication for DTV is completed, and its assembly begins.

Oct 1973 — Preliminary Design Review (Orbiter) is held as the Subassembly facility is ready-for-use and the FTV-1 will be ready to receive subassemblies.

Nov 1973 — The STV now moves into a position where segments of this vehicle can be assembled.

Dec 1973 — Detail fabrication for the Ironbird has been completed and its assembly starts.

Mar 1974 — During the period between November 1973 and January 1975, the Reaction Control System (WBS L5-02-03), the EC/LSS (WBS L5-02-06) and the Crew Station (WBS L5-02-07) will be installed into the FTV-1 Structure.

June 1974 — Subassembly Validation will take place as the subassemblies are installed into the FTV-1. On 1 July, FTV-2 will be ready for installation of subassemblies.

Sept 1974 — Final Assembly Log Books for STV and FTV-1 will be ready; the Manufacturing Facility will be ready- for-use in Final Assembly effort.

Oct 1974 — Installation, assembly, and checkout Critical Design Review (CDR) will be held. Final assembly of STV and FTV-1 will begin. The Orbital Manuevering System - OMS (WBS L5-02-03) and Simulated Rocket Engines (WBS L5-04) go into the Flight Test Vehicle.

Nov 1974 — The RCS (WBS L5-02-03), EC/LSS (WBS L5-02-06) and crew station (WBS L5-02-07) will be ready for installation into FTV-2. Avionics (WBS L5-02-05) and Power Systems (WBS L5-02-04) will be ready for final assembly into FTV-1.

1 Dec 1974 — All tool design will be released at this time.

Jan 1975 — Orbiter CDR. 90 percent of the detail drawings will be released.

May 1975 — Final Assembly and rollout of the STV will be completed and Static-Dynamic Tests (WBS L5-02-10) will begin. Production Planning will begin final assembly of the FTV-2 Log Books; final assembly procedures, will be validated and tool proving will be completed.

June 1975 — Final Assembly of the FTV-2 will be started with OMS (WBS L5-02-03) and the Prototype Rocket Engines (WBS L5-04).

July 1975 — The Avionics (WBS L5-02) and Power (WBS L5-02-04) system will be ready for final assembly into FTV-2.

Aug 1975 — Assembly of the Propulsion Development Module (PDM) (WBS L5-02-03) involves integration of Structures (WBS L5-02-02) with Rocket Engines (WBS L5-04) and Battleship Tank (WBS L5-07). This effort will span 90 days (to 1 Nov 1975) at which time it is moved to the missile test facility for Hot Fire Tests (Ground Test – WBS L5-02-10).

Sept 1975 — The facility will be ready for use for factory checkout operations. The ABES of the Propulsion (WBS L5-02-03) System will be ready for installation into FTV-1 at this time.

Oct 1975 — Factory checkout on FTV-1 will be initiated following completion of final assembly of this vehicle.

Dec 1975 — The Systems Test facility will be ready to prepare for start of systems test operations on the FTV-1 – scheduled 1 January 1976.

April 1976 — Systems Test will be finalized and validated; the FTV-1 will rollout to continue Ground Test which will precede Horizontal Flight Test (starting 1 July 1976).

June 1976 — Start of Factory checkout; 90 days span for FTV-2, as was done on FTV-1, and followed by four (4) months of tests and an Acceptance Flight Check (WBS L5-02-10). During the 60 day period following acceptance check FTV-2 is ferried to the launch facility to be used in the facility and GSE checkout.

An alternate plan is to have the vehicle undergo "cold flow" testing at the Mississippi Test Facility; this would require ferry to and from the MTF.

Aug 1977 — Engine installation, mating and checkout will be held at the launch facility on FTV-2.

PV-1 Structures will be ready for Subassembly – installation at the assembly facility. The spans and points at which installation has been determined to be made is based on the best available manufacturing planning considering all resources and the delivery requirements of subassemblies.

Feb 1978 — FTV-1 will complete Horizontal Flight Test and will be returned to the assembly facility for removal of test packages and refurbishment required for installation to an orbital configuration.

Mar 1978 — FTV-2 will have gone through mate and checkout for First Manned Orbital Flight from the launch facility.

April 1978 — FTV-1 continues with RCS (WBS L5-02-03), EC/LSS (WBS L5-02-06) and Crew Station (WBS L5-02-07) being installed. The Assembly Facility is involved concurrently with installation on Production Vehicle 1 (PV-1), the spans for this operation are similar to FTV-1 and -2.

Feb 1979 — Following Systems Test, FTV-1 will undergo an Acceptance Flight Check (WBS L5-02-10) to rollout in an Orbital Configuration.

Feb 1980; 1981; 1982 — The Production Vehicles PV-1, -2, and -3 will be ready for Operations after the normal installation, assembly and checkout previously discussed.

5.7.3 Schedule Risks

(1) The assembly facility must be ready to receive the first vehicle on the October 1973 date shown.

(2) Any late drawing release will cause a schedule slippage, as well as a subsystem not being delivered to the facility as shown.

(3) Early resolution of the location of each facility is critical to the installation, assembly, and checkout activity.

(4) The requirements (logistics) for transporting of all structures, systems, subsystem, and assemblies must be recognized and resolved early in order to determine the most economically feasible movement of these units.

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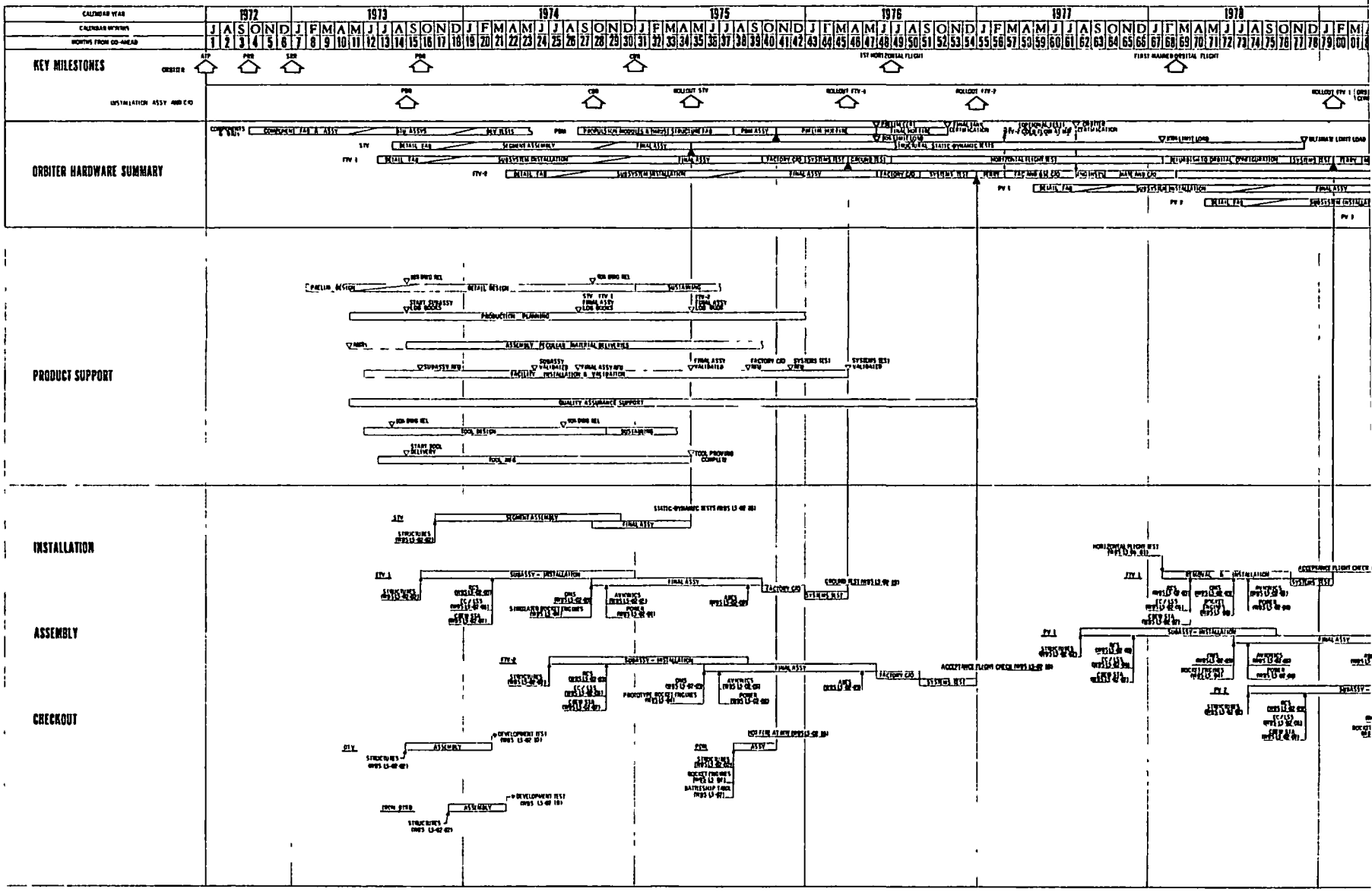
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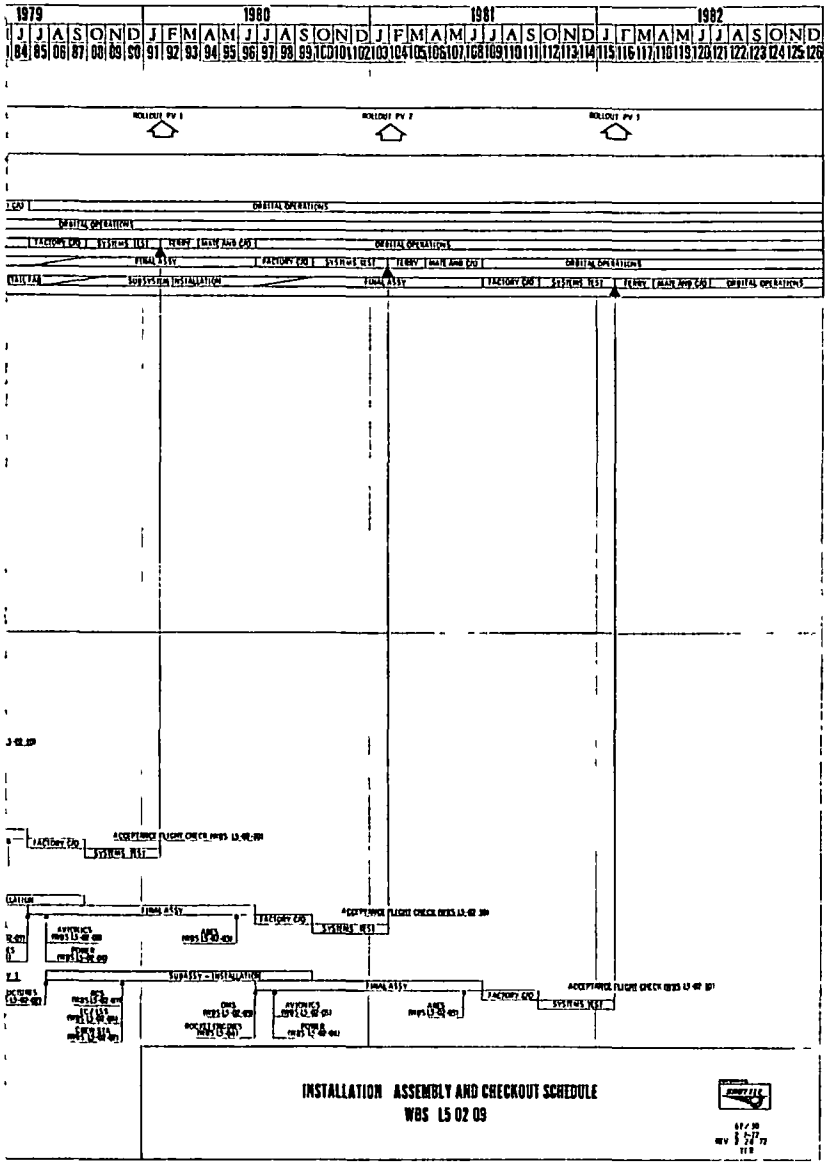

Fig. 5-7 Installation, Assembly, and Checkout Schedule

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5.8 ORBITER GROUND TESTS (WBS Level 4, L5-02-10)

The ground test activity schedule, Fig. 5-8, portrays the development and qualification testing of major hardware items. Component and subassembly development and qualification testing is included under their respective WBS elements. Included in this WBS task are testing of the STV, Ironbird, PDM, DTV, major structural assemblies, and the wind-tunnel testing that leads to the aerodynamic configuration and flight systems characteristics definition.

The orbital ground tests WBS element includes all effort and materials required to plan and perform the integrated subsystems, system and vehicle level tests on the Orbiter flight and ground support equipment that are necessary to evaluate and verify the integrity and performance of this hardware. Included are development, certification, and acceptance testing of flight hardware and ground support equipment. The ground support equipment utilized in this test program includes the Ironbird, the propulsion development module (PDM), the structural test vehicle (STV). The flight hardware includes all five orbital vehicles.

5.8.1 Products and Services

The deliverable products of this WBS element are the test reports and all other data specified as DRL items.

5.8.2 Schedule Rationale

The Ground Test program will be actively underway soon after Orbiter System Requirements Review (SRR) beginning with an update of the test plan. The first two major elements to be started are the structural test vehicle (STV) and the Ironbird. The test program for the STV will be started by receiving input data from materials/processes functional development tests and inputs from prime structural components and mechanisms tests. At the same time, planning for the development of an appropriate structural test facility will be started. During the remainder of the time prior to Orbiter Preliminary Design Review (PDR), the STV criteria will be refined, the preliminary design will be developed and component fabrication will be started. Also, in this period development of a battleship test facility for the Ironbird will be started.

During the 15 months between Orbiter PDR and Critical Design Review (CDR), most of the development testing will be started and well into the program. Test activities underway include: STV - detail fabrication and segment assembly complete, final assembly started, perform critical localized static load tests to 80 percent limit, verify crew compartment pressure loading capability, complete the segment vibration/acoustic development tests, and determine the modal dynamics of the wings and fins; Ironbird - develop battleship test facility and perform functional development and certification tests; PDM - complete design utilizing inputs from structures and propulsion, start detail fabrication; DTV - develop test complex facility, fabricate segments structure, install equipment, perform integrated system functional development test and software compatibility/validation. After component CDRs, upgrade DTV with production items and continue test program until all test items are production units. The results of all test activities will be used in support of CDR.

The start of the horizontal flight test program is the next major milestone and is planned for 18 months after Orbiter CDR. This period encompasses FTV-1 activities from final assembly through factory checkout, systems test, and ground test, to ready for first flight test. FTV-2 will complete subsystem installation, final assembly, and start factory checkout. Parallel to these vehicle activities, the ground test program will be continuing: DTV - perform system certification tests on vehicle segments in operational environments; demonstrate EMC compativility with interconnected vehicle segments; STV - perform the planned static load and fatigue tests on wings and fins, complete assembly of STV and perform vehicle static 80 percent limit load test; i.e., critical loads, life cycles, and failure modes; PDM - complete propulsion module and thrust structure fabrication, assemble PDM, perform functional development tests utilizing a dummy engine, perform propellant cold-flow tests using boilerplate tanks and simulated engine plumbing, upgrade PDM by installing test engines and test instrumentation, initiate preliminary static hot fire tests, complete test series and obtain preliminary certification. The FTV-1 systems acceptance test for horizontal flight will be accomplished at the factory. Conduct modal survey on FTV-1 in preparation of first flight test.

The horizontal flight test program will span a 19-month period and will be concluded approximately one month prior to the first manned orbital flight. The STV structural static and dynamic test program will continue until 100 percent limit load has been achieved. The PDM propulsion tests will continue through the final "hot-fire" series utilizing a production tank until final certification has been obtained. The last ground test activity in this period is the FTV-2 system acceptance test at the factory prior to ferry operations. Successful conclusion of FTV-1 horizontal flight test operations and the STV structural test program to 100 percent limit load are constraining on the first manned orbital flight schedule. An optional ground test for this period is propellant cold-flow test at MTF utilizing the FTV-2.

The orbital flight operations will continue to the end of the program and this span encompasses the following ground tests: STV - complete the structural series ending with ultimate loading; PV-1, PV-2, and PV-3 - systems acceptance test to orbital operations criteria.

5.8.3 Schedule Risk

One potentially schedule - critical ground test program is the STV structural static/dynamic series. The program must achieve 80 percent limit load prior to start of horizontal flight test and 100 percent limit load prior to first manned orbital flight.

Another key and pacing test is the hot flow testing of the PDM leading to preliminary certification prior to FTV-1s first flight. Not only are the availability dates of the propulsion test engines tight, but the overall test span leading to this certification is significantly shorter than that of the Saturn S-II-1 vehicle.

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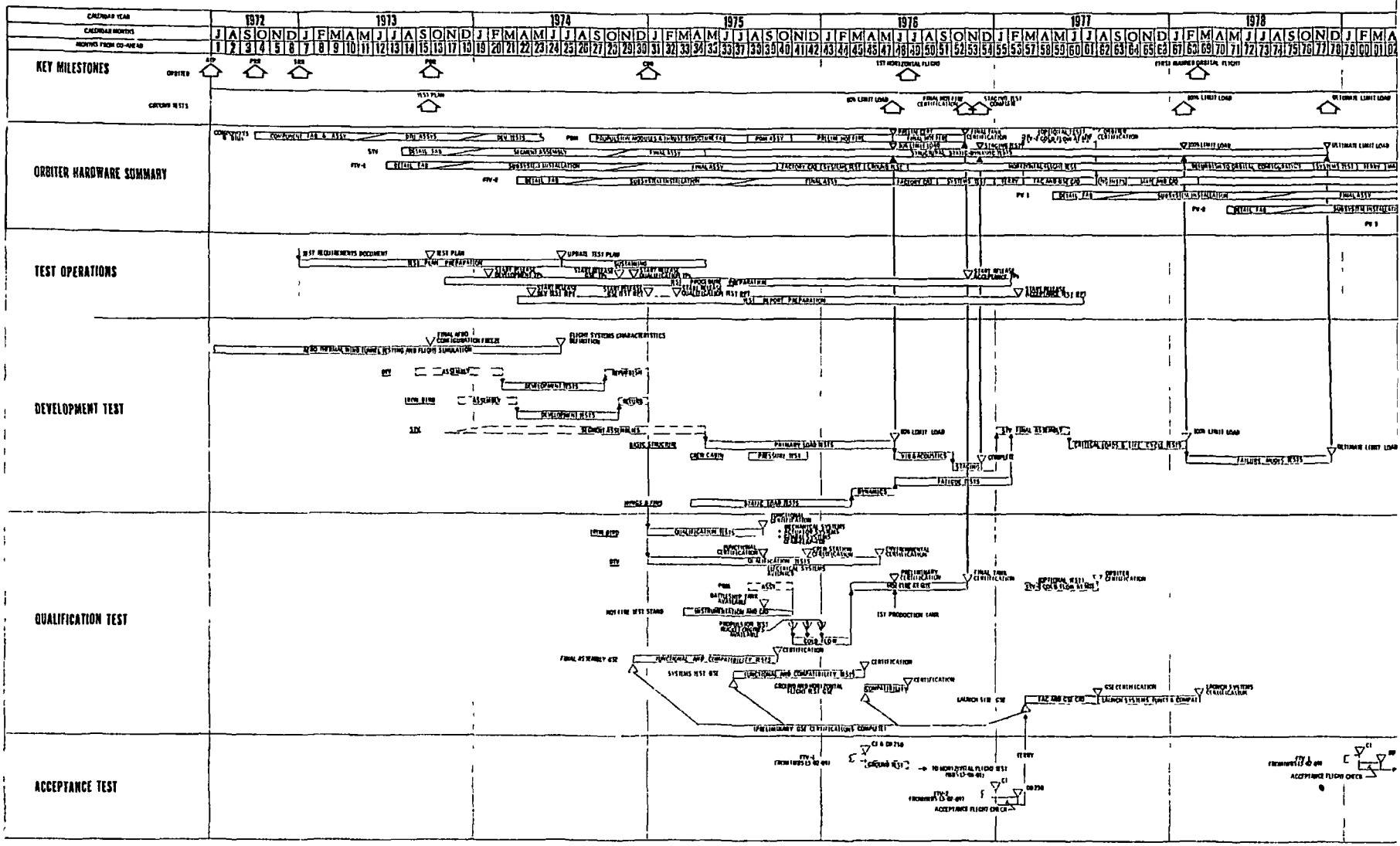
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MONTHS FROM GO-AHEAD
KEY MILESTONES
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CERTIFIED
1ST PLANE
1ST HORIZONTAL FLIGHT
FIRST MANNED ORBITAL FLIGHT
80% LIMIT LOAD
ULTIMATE LIMIT LOAD
ORBITER HARDWARE SUMMARY
TEST OPERATIONS
DEVELOPMENT TEST
QUALIFICATION TEST
ACCEPTANCE TEST

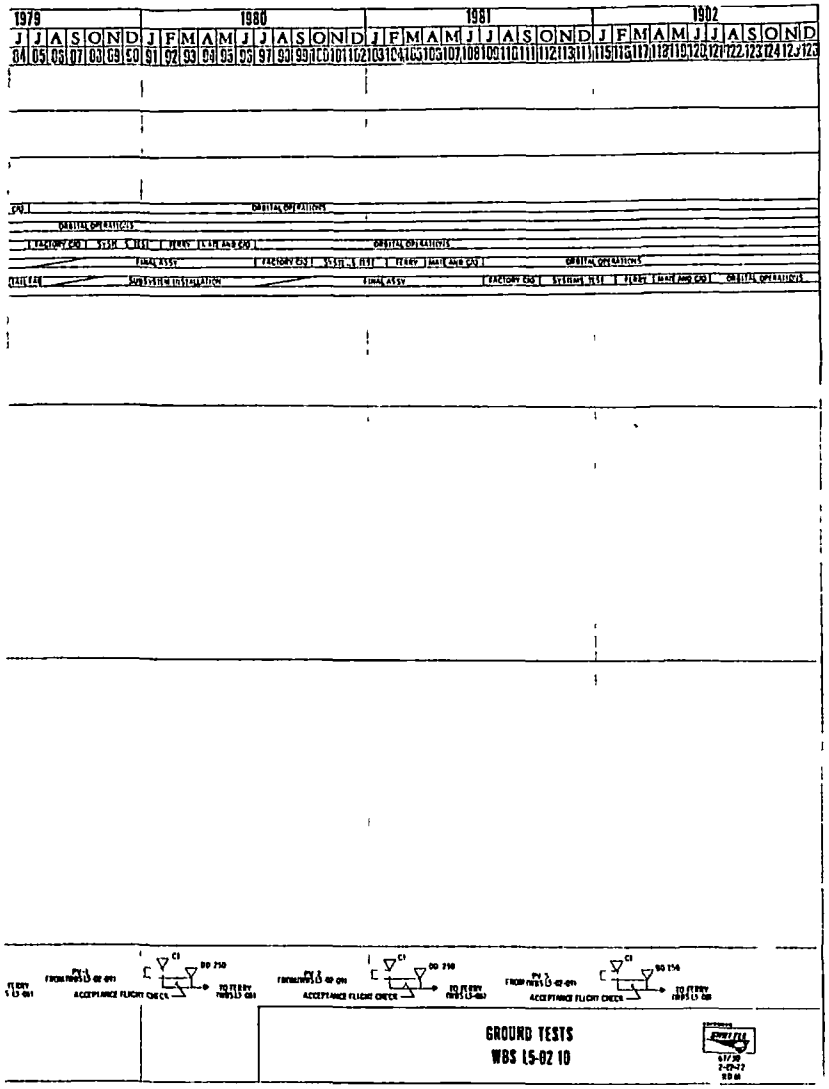

Fig. 5-8 Ground Tests

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5.9 ORBITER FACILITIES (WBS Level 4, L5-02-11)

The Facilities Schedule, Fig. 5-9, reflects the planning, requirements analysis, design, construction, and occupancy activities necessary to provide program facilities in a timely manner. Emphasis has been placed on maximum utilization of existing facilities.

The Facilities WBS element refers to the facilities required to develop, produce, and test the Orbiter System or portions thereof. This element also includes equipment acquisition, modernization and maintenance of the facilities or equipment. This element includes facilities planning, design and layout, procurement, construction, installation and reporting.

5.9.1 Products and/or Services

This effort is subdivided into:

- Facilities Planning, Design, and Construction
- Facilities Activation
- Operations Facilities

(a) Facilities Planning, Design, and Construction include all the elements of planning, design construction, quality control, testing and acceptance necessary to provide for such operation. These elements will include preparation of criteria for engineering studies; making engineering studies and preparation of reports; designing; preparing drawings and specs; construction, inspection, and testing; and providing maintenance and operation procedures.

(b) Activation shall include validation of facilities characteristics and interface, the installation and checkout of equipment, and verification of the compatibility of the facility with GSE and the Orbiter Vehicle.

(c) Operation Facilities will include identifying and determining all facilities needed in support of the operations of the Orbital Vehicle, including facilities requirements at the vertical flight test site and alternate landing and ferry operations sites.

Wherever possible, existing facilities will be used.

5.9.2 Schedule Rationale

All desk and board facilities to support the Administrative functions (Program Management, Vehicle Project Management, Computer/Manufacturing and Training) will be quickly activated and ready for use approximately at the Orbiter milestone of Authority to Proceed (ATP). From ATP to Program Requirement Review (PRR), modifications to the Sunnyvale Manufacturing facilities for detail parts and tool fabrication (Bldg. 159) will be made and the fabrication area will be ready for use a week before the start of Component Fabrication and Assembly. Also during this time span, modifications for Clean Room (C/R) to Major Subassembly facilities will get underway at Sunnyvale. Classroom-type training facilities will be activated at all required locations. It is necessary also, during this time span, that the preliminary design (followed later by construction, modification, and certification) begin for the External Tanks manufacturing and testing facilities.

The C/R modifications to the Major Subassembly facilities will be completed and ready for use one week prior to the Orbiters System Requirement Review (SRR) milestone. This time span between PRR and SRR (90 days) will show the continuation of start up to the Manufacturing and Test facilities for the external tanks.

Between SRR and the Orbiters milestone of Preliminary Design Review (PDR), modifications to the component manufacturing facilities for external tanks will be completed and ready for use. This ties in with the start of Detail Fabrications for FTV-1.

From PDR to the next major milestone of the Orbiter, the Critical Design Review (CDR), a 15-month span occurs. During this time the Vehicle Final Assembly Facilities at Palmdale, including white room areas, will be modified and completely ready for use on 1 September 1974. This date will be one month prior to the start of final assembly of the STV and FTV-1. With this facility complete, all manufacturing facilities are now available for use and occupancy. In support of this manufacturing effort, warehousing facilities will be activated at both Sunnyvale and Palmdale, and will remain occupied and maintained through the entire program. Additionally, the

Development Test Facilities will be activated and ready for use in time for the start of development tests of components and DTVs. During this same span between PDR and CDR, the manufacturing facilities for external tanks has been activated and the Component Test and Test Tank Facilities for external tanks are scheduled to be certified and then ready for use.

Prior to the next major milestone of the Orbiter – the first Horizontal Flight – all ground test facilities are completed and ready for use. First, the Structural Test Facilities will be activated by April 1975 and ready for use for the start of the structural (static and dynamic) tests of STV. Then, the Hot-Fire Facilities become ready for use by 1 October 1975, which is one month prior to PDM's preliminary Hot Fire; and lastly, the System Test Facilities are activated and are ready for use in November 1975, four months prior to the ground testing on FTV-1. During this time period, the activation of the Horizontal Flight Test Facilities have been completed and are ready for use two weeks prior to the first Horizontal Flight of FTV-1 on 1 July 1976.

During the 20-month period between first Horizontal Flight and first Manned Orbital Flight, six significant facility milestones are reached. These are:

(1) The final Hot Fire Testing Program will be completed and its facilities phased out at the end of October 1976.

(2) The Maintenance and Modifications Facilities at the Launch Site are activated by 1 March 1977, to be ready for the cold flow tests of FTV-2 if that optional test series is selected.

(3) The modifications to the Launch and Recovery facility are completed and it is ready for use in July 1977. This provides an 8-month period before the first Manned Orbital Flight.

(4) The Horizontal Flight Program is completed and the Horizontal Flight Test facilities are closed in February 1978.

(5) The development testing of the External Tank is completed on 1 May 1977 and its facilities will be closed.

(6) The Storage Facilities for the External Tanks have been activated and are ready for use in July 1977, three months prior to Final Tank Certification and one month prior to the first production tank being produced.

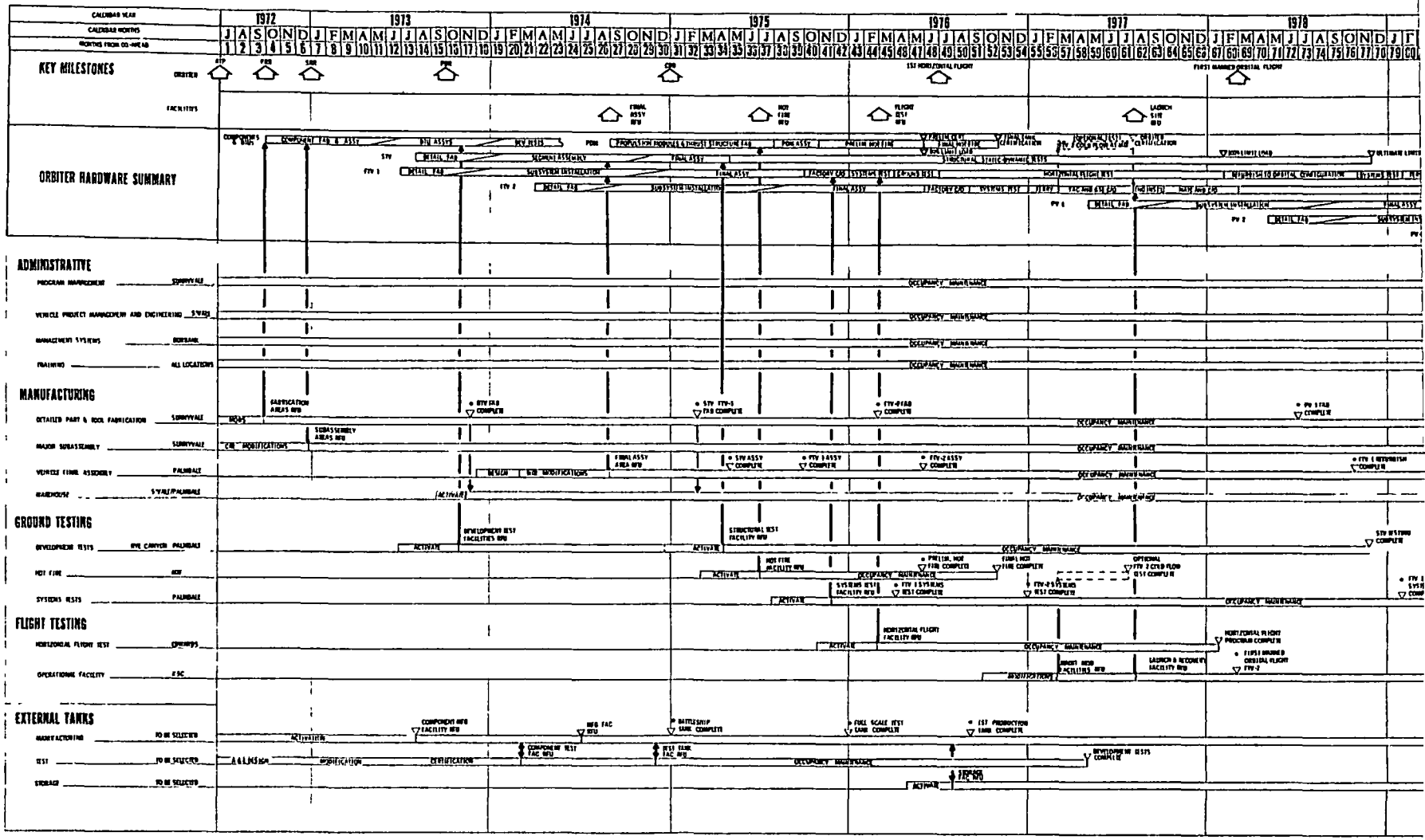
After the First Manned Orbital Flight and for the remainder of the program, the following facility closures occur:

(1) The testing of the STV is completed when the ultimate limit load is reached on 1 December 1978. With this happening, the Development Ground Testing Facilities are closed.

(2) The Manufacturing Major Subassembly Facility is closed on 1 March 1981.

(3) With the completion of PV-3 fabrication, the Manufacturing Detailed Parts & Tool Fabrication facilities will be phased out on 1 July 1981.

(4) On 1 February 1982, with the completion of the PV-3 fabrication and testing, the Vehicle Final Assembly and the Systems Test Facilities are phased out.


CALENDAR YEAR
1972
1973
1974
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1976
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CALENDAR MONTHS
MONTHS FROM OS-ARRIVAL
KEY MILESTONES
ORBITER
ATP
FRR
SRR
PDR
CDR
1ST HORIZONTAL FLIGHT
FIRST MANNED ORBITAL FLIGHT
FACILITIES
FINAL ASSY RFD
HOT FIRE RFD
FLIGHT TEST RFD
LAUNCH SITE RFD
ORBITER HARDWARE SUMMARY
ADMINISTRATIVE
PROGRAM MANAGEMENT
SUNNYVALE
VEHICLE PROJECT MANAGEMENT AND ENGINEERING
SYLMAR
MANAGEMENT SYSTEMS
DOWNEY
TRAINING
ALL LOCATIONS
MANUFACTURING
DETAILED PART & TOOL FABRICATION
SUNNYVALE
FABRICATION AREAS RFD
MAJOR SUBASSEMBLY
SUNNYVALE
SUBASSEMBLY AREAS RFD
VEHICLE FINAL ASSEMBLY
PALMDALE
FINAL ASSY AREA RFD
WAREHOUSE
SYLMAR/PALMDALE
ACTIVATE
GROUND TESTING
DEVELOPMENT TESTS
SYLMAR CANYON PALMDALE
DEVELOPMENT TEST FACILITIES RFD
HOT FIRE
MDC
HOT FIRE FACILITY RFD
SYSTEMS TESTS
PALMDALE
SYSTEMS TEST FACILITY RFD
FLIGHT TESTING
HORIZONTAL FLIGHT TEST
DOWNEY
HORIZONTAL FLIGHT FACILITY RFD
OPERATIONAL FACILITY
KSC
EXTERNAL TANKS
MANUFACTURING
TO BE SELECTED
COMPONENTS RFD
FACILITY RFD
MFG FAC RFD
TEST
TO BE SELECTED
COMPONENT TEST FAC RFD
TEST TANK FAC RFD
STORAGE
TO BE SELECTED
ACTIVATION
QUALIFICATION
CERTIFICATION
OCCUPANCY MAINTENANCE
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MODIFICATIONS
BUILDINGS
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BRIDGE
B/B MODIFICATIONS
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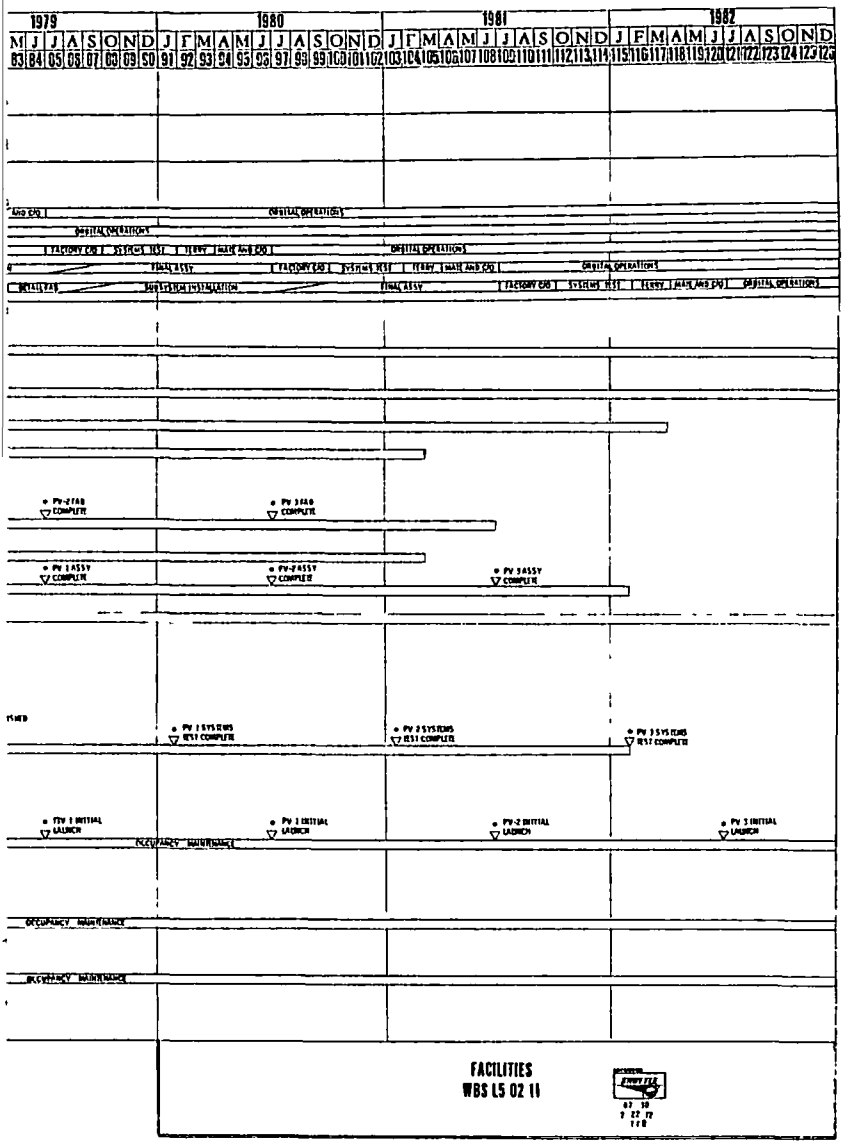

Fig 5-9 Facilities

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5.10 ORBITER SYSTEM SUPPORT (WBS Level 4, L5-02-12)

The orbiter system support elements include all of the hardware, software, support services, and technical data required to support the orbiter vehicle in the test and operational phases.

Hardware includes all of the equipment, other than standard laboratory equipment or systems, required to accomplish the development, qualification/certification, and acceptance testing of the orbiter vehicle as well as the equipment required to support the ground and flight test and operational phases of the orbiter program. This element also includes launch, checkout, handling and transportation equipment, and that equipment required to verify that the installed ground support systems are functioning correctly prior to use with the orbiter vehicle.

Software includes the computer programs necessary to operate the support equipment during ground equipment checkout.

Support services include logistics management and operations and spares, production and quality assurance planning, training services and aids, and transportation required to support maintenance and servicing of the orbiter vehicle and orbiter support equipment during development and production.

Technical Data consists of handbooks, manuals, and maintenance, repair, and checkout procedures required to operate, maintain, and service the vehicle and ground equipment.

Work effort includes all engineering design and analysis; tool design, fabrication, and maintenance; manufacturing of special test equipment; quality control; inspection; and procurement activities; plus propellants and gases required. This element also includes all test and support articles design and fabrication of the mockups, fabrication of all spares and repair of hardware.

Figure 5-10 illustrates the schedule activities for the Orbiter System Support.

5.10.1 Schedule Rationale

No systems support effort will be expended before the Orbiter's Program Requirements Review milestone on 1 October 1972. At this time and up through the Orbiters System Requirements Review milestone on 1 January 1973, advance material requests will be initiated and the designing of development tools will begin.

During the next nine months – through Orbiter Preliminary Design Review – the tool and equipment design effort will continue and some delivery of material will be received.

Between the Orbiter major milestones of Preliminary Design Review and Critical Design Review (1 January 1975) a concentrated engineering design effort will be underway. Preliminary design will be completed prior to the Systems Support's Preliminary Design Review scheduled for June 1974. All final design will be completed prior to the Orbiter CDR with the exception of AGE checkout equipment. The fabrication and assembly of factory checkout equipment, fluid service checkout equipment, and Propulsion Development Modules (PDM) checkout equipment will begin. The Production Test Support Equipment Test Plan will also be developed.

For the next 18 months, culminating with the first Horizontal Flight, engineering design will be sustained/maintained. Also the fabrication, assembly, installation and proofing of equipment is completed so that all Checkout Equipment (factory, PDM, and AGE) is ready for use in September 1975; all Servicing Equipment is ready for use in April 1976; and all AGE checkout equipment is ready for use for the Horizontal Flight Test (WBS L5-02-10) on 1 July 1976. The System Support Critical Design Review will be held in May 1975.

Also during this period, the Logistics Support Equipment Plan, the Operations Test Support Equipment and Inspection Plan, and the Maintenance Equipment Plan are developed and implemented to support FTV-1 flight. Complete System Support services are provided for the first Horizontal Flight.

The next time span from first Horizontal Flight to the First Manned Orbital Flight covers 20 months. All System Support efforts – equipment and services – are completed to meet the schedule of the WBS element Ground Test (WBS L5-02-09) which coincides with the engine installation of FTV-2 on 1 August 1977. Also, during this period and in support of FTV-2, System Support efforts will be supplied for engine installation checkout equipment, packaging, transportation, logistics and maintenance to ensure that the Systems Support major milestone of Launch & Support Equipment RFU one month prior to the First Manned Orbital Flight is met.

For the remainder of the program and in support of PV-1, PV-2, PV-3 and the refurbishment of FTV-1 and FTV-2 schedules, all continuing support services are provided. This consists of test and inspection support, orbital operation support, package operation support, transportation operation support, factory checkout equipment refurbishment support, logistic support, operations support and maintenance support.

5.10.2 Schedule Risk

Early firm design of the Orbiter Systems and Flight hardware is essential to the development of the checkout and support equipment. The development of the various items of support equipment will require a definition of the location and period of time when the equipment will be used and the relocation (move) of such equipment from development to production to operational support. Support equipment design should consider the possibility of redesign from one phase to another to preclude having to scrap such equipment as vehicles move into Operational Support.

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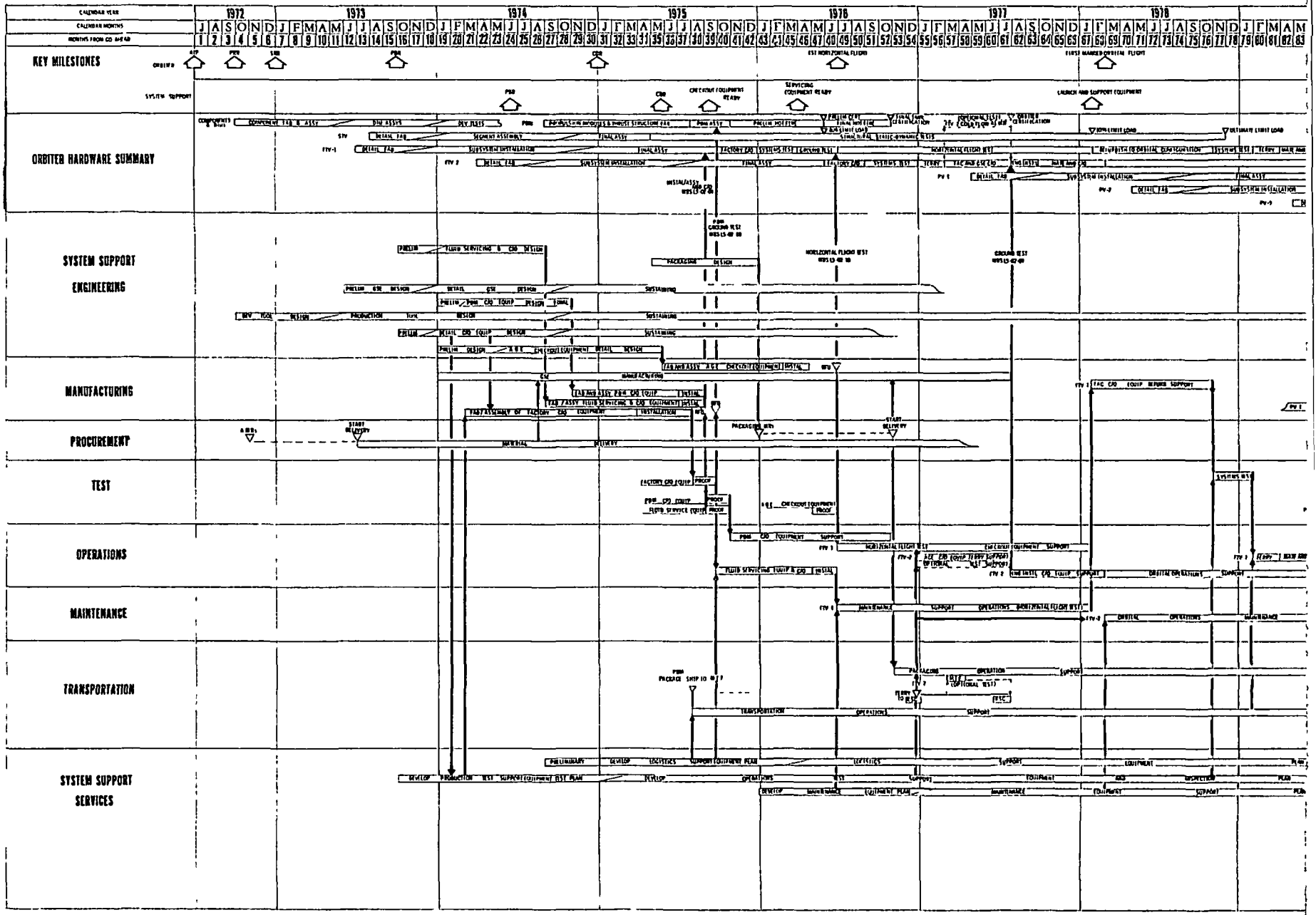
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CALENDAR MONTHS
MONTHS FROM GO AHEAD
KEY MILESTONES
ORBITER HARDWARE SUMMARY
SYSTEM SUPPORT ENGINEERING
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PROCUREMENT
TEST
OPERATIONS
MAINTENANCE
TRANSPORTATION
SYSTEM SUPPORT SERVICES

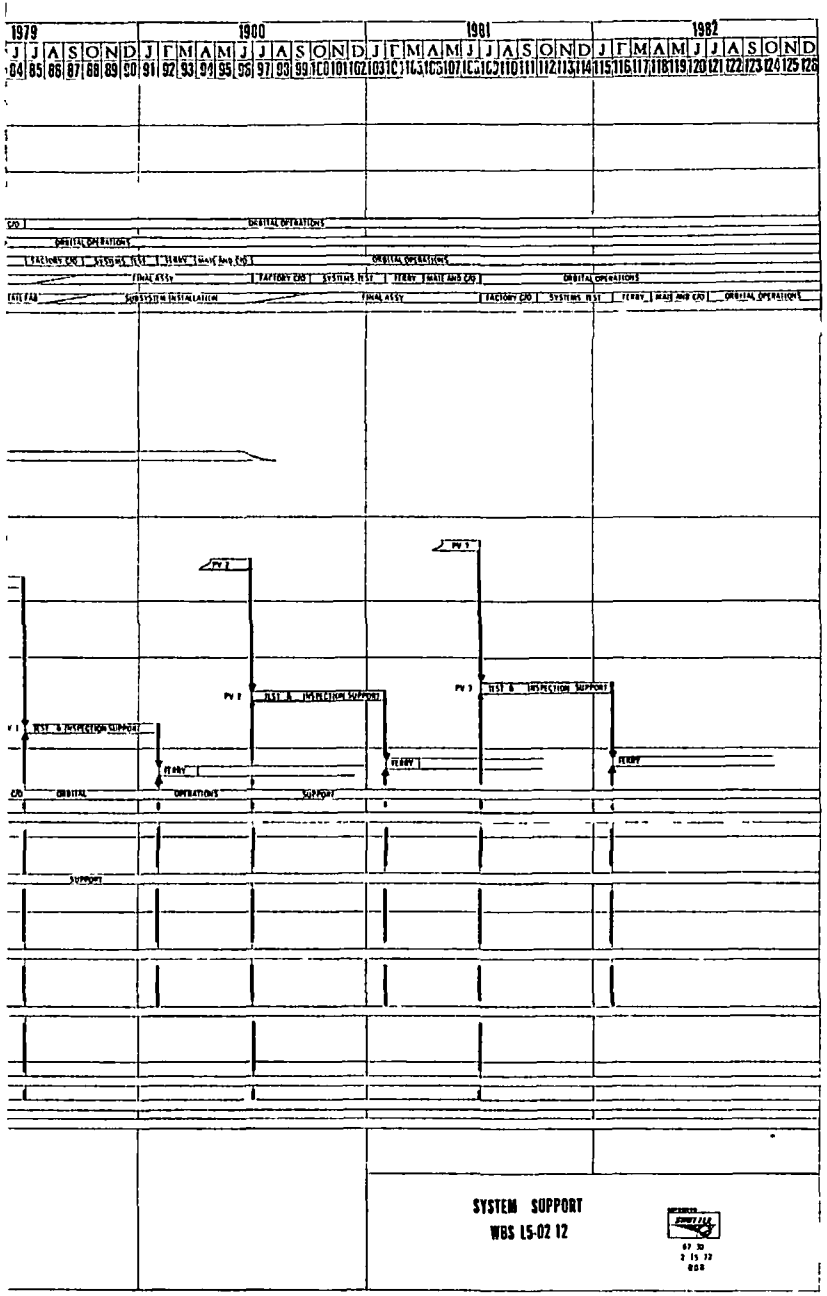

Fig. 5-10 System Support

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5.11 ORBITER HORIZONTAL FLIGHT TEST (WBS Level 4, L5-06-01)

This WBS element is based on the orbiter vehicle flight test program beginning with the turnover of the FTV-1 vehicle from Manufacturing following the completion of systems test.

The tasks to be acomplished in the Horizontal Flight Test are shown in Fig. 5-11, and include the planning, preparation, and conduct of all test operations, materials and supplies, and support services required to conduct the Horizontal Flight Test phase of the "Flight Test Operation" (WBS L5-06-01). Preflight ground tests and flight tests are included along with the servicing, maintenance and necessary refurbishment of the FTV, support equipment and facilities to assure successful accomplishment of the tests.

Upon completion of preflight ground testing, the Flight Test Vehicle (FTV-1) will be ground transported from the Lockheed (Palmdale) final assembly facility to Edwards AFB for start of the Flight Test Phases. The schedule delineates the major activities starting with vehicle release from the manufacturing and assembly operation to its return from refurbishment to orbital configuration.

5.11.1 Products and Services

The products resulting from this activity are basically documentation in the form of test plans, procedures and reports covering preparation and support of ground flight requirements to accomplish the horizontal flight envelope for the Orbiter.

5.11.2 Schedule Rationale

Writing of the Test Program Plan, which will include the Horizontal Flight Test phase, will be started following the Orbiter System Requirements Review (SRR). A preliminary plan will be ready three months after PDR. This preliminary test plan will be coordinated with the facilities and support equipment requirements by 1 March 1974 in order that an efficient test operation (preliminary) plan can be developed 30 days later. No later than 1 November 1974, the test instrumentation requirements for conducting the tests must be firm. These requirements are critical since the FTV-1 is in the last

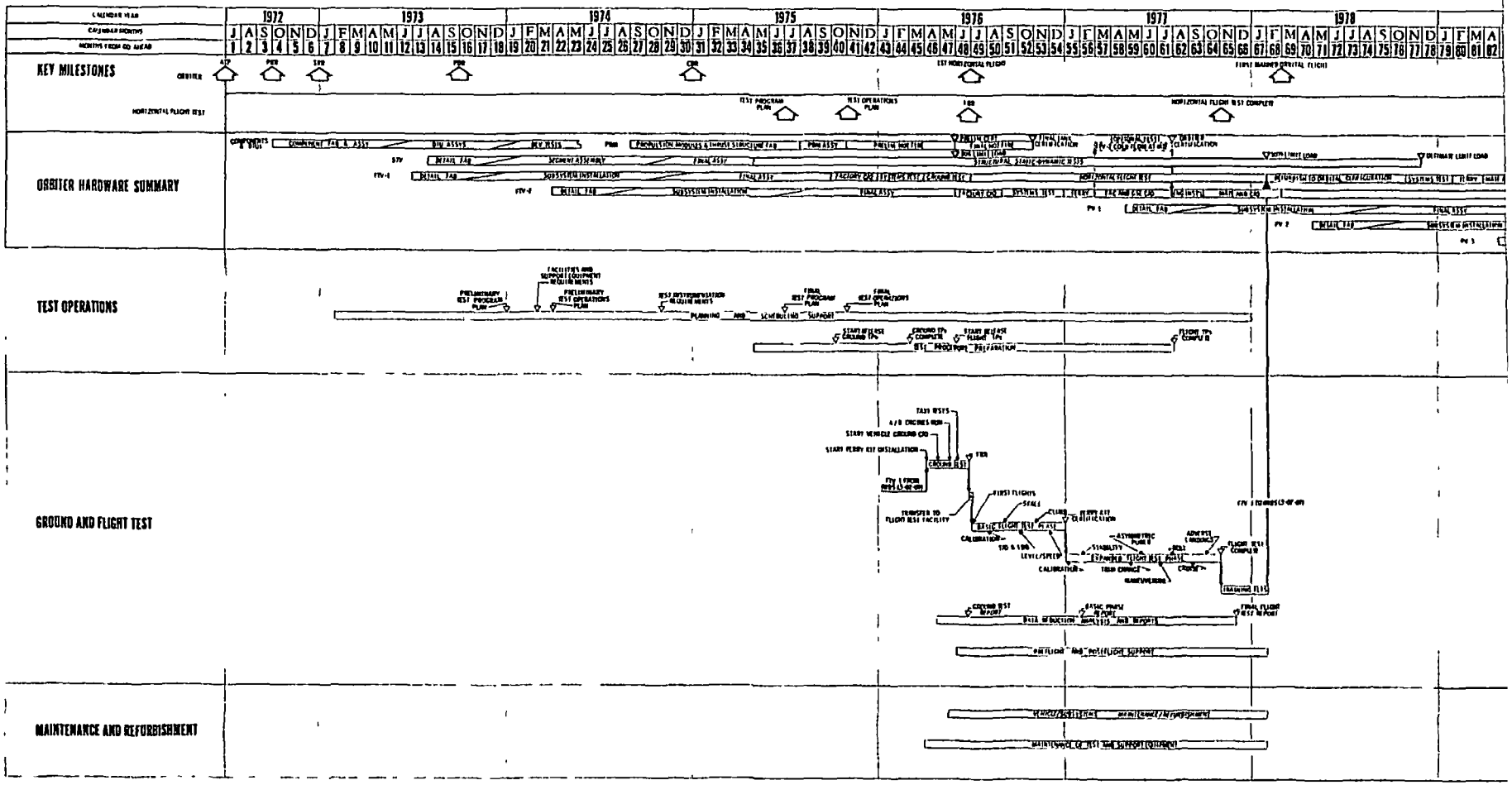
60-day period of Subsystem Installation and the date for Orbiter CDR coincides with the conclusion of subsystem installation and the start of Final Assembly on this vehicle.

A Final Test Program Plan will be published by 1 July 1975 when FTV-1 has passed the 75 percent completion point in Final Assembly. The Ground Test Plans must be started and the Final Test Operations Plan made ready during the next four months. The Ground Test plans must be complete 30 days prior to their application on FTV-1. Installations, checkouts, engine runs and taxi tests peculiar to this vehicle will span the period from 1 April 1976 to 1 July, when the FTV-1 will be transported to the Flight Test Facility. The Ground Test Report will be produced and will eventually become part of the Final Report for Horizontal Flight Tests. The Flight Readiness Review (FRR) will be submitted to become part of this documentation package.

The Basic Flight Test phase will be conducted during the six-month period between 1 July and 1 January 1977. Close coordination will be maintained between the flight line for this and the Expanded Flight Test and the assembly facility as a backup to the maintenance activity. This phase will be followed by the Expanded Flight Tests to assure operational capability in the areas of performance, stability control and flying qualities which are to be used in the training flights, which will close out the total Horizontal Flight Test effort. In-flight refueling of the FTV-1 may be included. All data and reports will be analyzed by the end of the training flights and 30 days prior to the First Manned Orbital Flight of FTV-2.

5.11.3 Schedule Risks

The greatest risk to the accomplishment of a successful Horizontal Flight Test is the single vehicle concept even though the horizontal flight test requirements are not as severe as military or commercial aircraft. Any test problems causing vehicle down time for rework will delay final flight test completion, which is a constraint for FMOF. An earlier start on FTV-2 would reduce the schedule risk in the event a major problem occurs during the fabrication, installation and assembly of the FTV-1 or early in its basic flights. The early initiation of work on the FTV-2 and inclusion of this vehicle in the flight test program would tend to raise the confidence level of this vehicle in preparation for First Manned Orbital Flight. A period of refurbishment (or potential refurbishment) would be required. In addition more rework would result if there were any design changes resulting from horizontal flight test.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CDR
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FIRST MANNED ORBITAL FLIGHT
HORIZONTAL FLIGHT TEST
TEST PROGRAM PLAN
TEST OPERATIONS PLAN
FRR
HORIZONTAL FLIGHT TEST COMPLETE
ORBITER HARDWARE SUMMARY
TEST OPERATIONS
PRELIMINARY TEST PROGRAM PLAN
PRELIMINARY TEST OPERATIONS PLAN
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GROUND AND FLIGHT TEST
TAXI TESTS
FIRST FLIGHTS
CALIBRATION
MAINTENANCE AND REFURBISHMENT

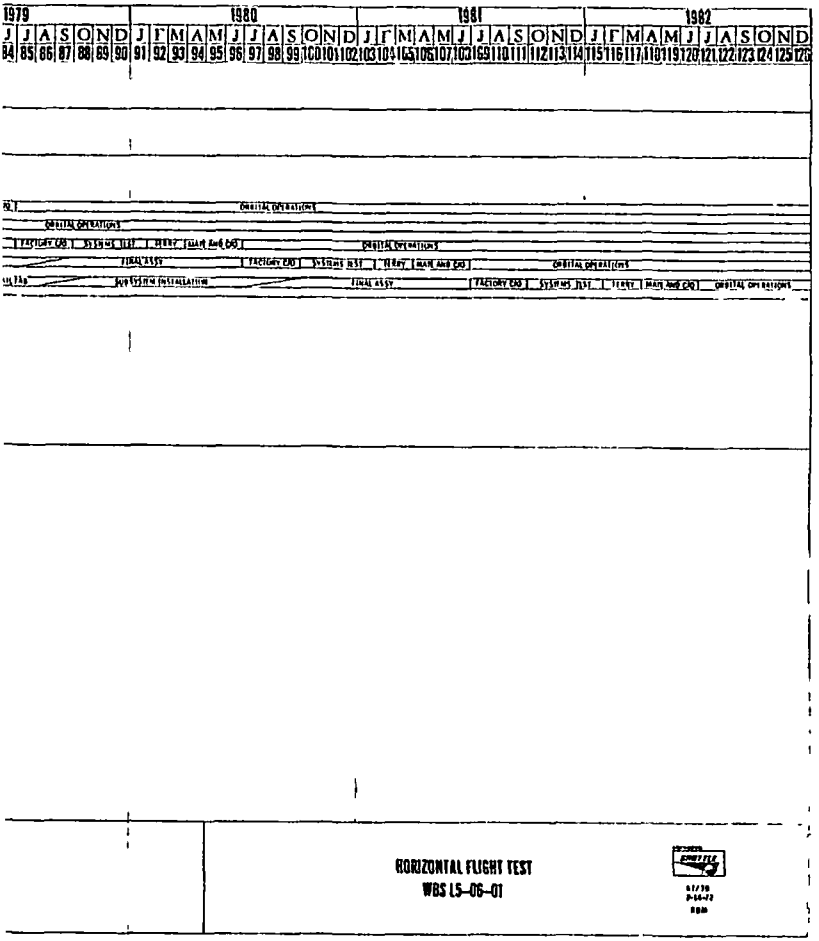

Fig. 5-11 Horizontal Flight Test

APPENDIX

WORK BREAKDOWN STRUCTURE

Engineering Memorandum L5-M1

ENGINEERING MEMORANDUM

TITLE: WORK BREAKDOWN STRUCTURE FOR PHASE B EXTENSION STUDY	EM NO: L5-M1 REF: DATE: 5 November 1971
AUTHORS W. D. James	APPROVAL: ENGINEERING SYSTEM ENGRG

PROBLEM STATEMENT

A Work Breakdown Structure (WBS) for the Two-and-One-Half-Stage Phase B Extension Space Shuttle Configuration is required for identification and ordering of all Lockheed engineering activities. The required WBS must comprise all hardware and software elements of the program and be identifiable down to WBS Level 5.

RESULTS

A Work Breakdown Structure has been developed for the orbiter, booster (both reusable and expendable), external tanks, operations, and total shuttle program integration. Flight hardware, associated support systems, and technical data have been identified to the subsystem level (WBS level 5).

Affected Work Breakdown Structure Elements

None

ANALYSIS

A summary of the major WBS elements (Level 4) is shown in Figure 1. The detailed breakdown to Level 5 follows.

For the purpose of identifying EM's under this follow-on study, only Level 4 WBS elements will be used. Two exceptions are the Space Shuttle System Integration (L5-01) and Orbiter Structures, (L5-02-02) which will be identified to Level 5.

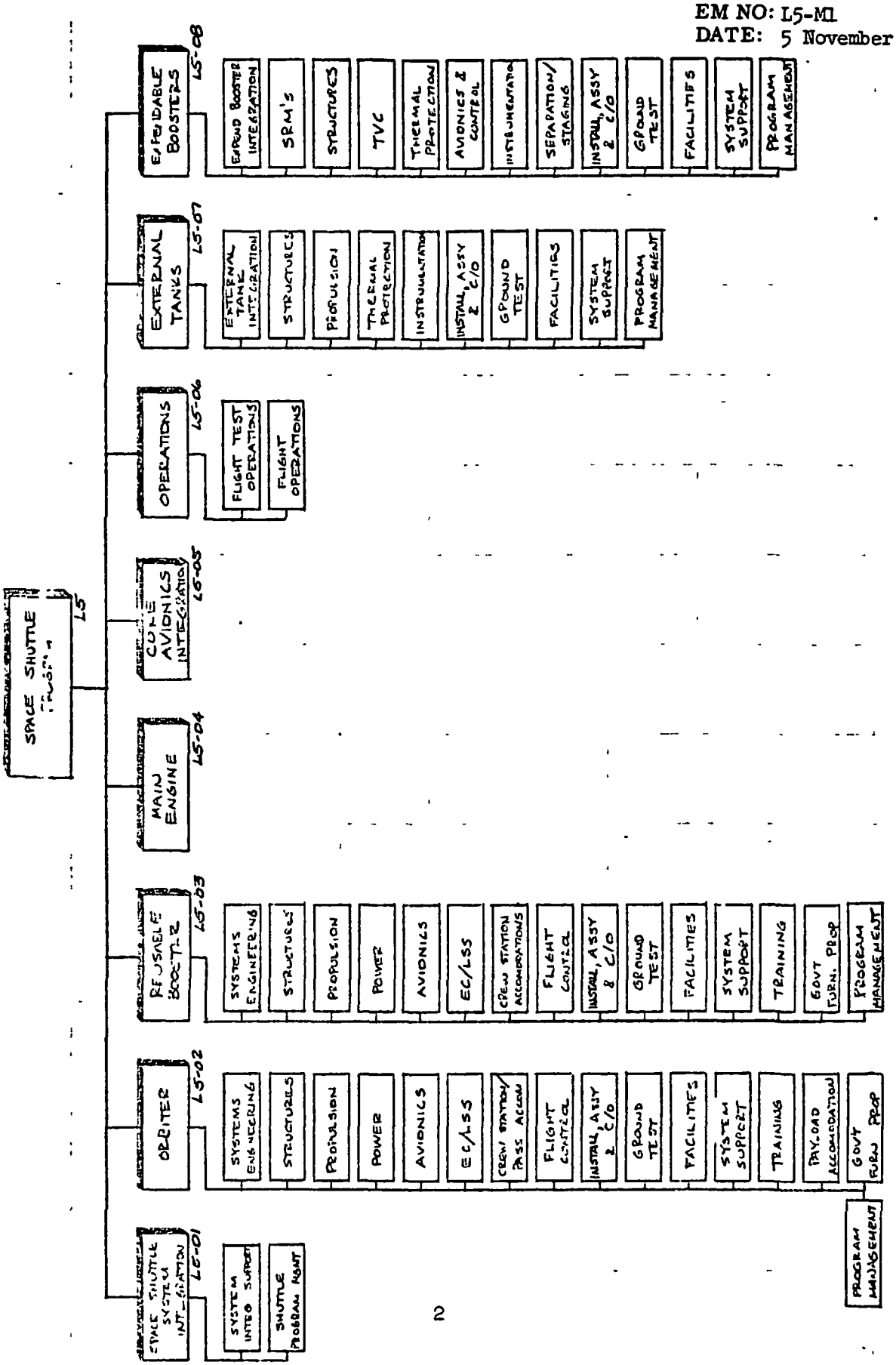

Fig. 1 Major Work Breakdown Structure Elements

WORK BREAKDOWN STRUCTURE
TWO-AND-ONE-HALF-STAGE

WBS Code	WBS Level	Title
L5	2	Space Shuttle Program
L5-01	3	Space Shuttle System Integration
L5-01-01	4	Space Shuttle System Integration Support
L5-01-01-01	5	Systems Integration
L5-01-01-02	5	Systems Requirements and Mission Analysis
L5-01-01-03	5	Systems Analysis and Trade Studies
L5-01-01-04	5	Systems Performance and Sizing Sensitivities
L5-01-01-05	5	Systems Aerodynamic and Aerothermodynamic Analysis
L5-01-01-06	5	Shuttle System Test Program Analysis
L5-01-01-07	5	Interface Definition and Control
L5-01-01-08	5	Shuttle Systems Effectiveness
L5-01-02	4	Space Shuttle Program Management
L5-01-02-01	5	Program Performance Management
L5-01-02-02	5	Program Configuration Management
L5-01-02-03	5	Program Interface Management
L5-01-02-04	5	Program Commonality Management
L5-01-02-05	5	Program Logistics Management
L5-01-02-06	5	Program Plans
L5-01-02-07	5	Program Schedules
L5-01-02-08	5	Program Costing
L5-01-02-09	5	Program Documentation
L5-01-02-10	5	Program Contract Management

WBS Code	WBS Level	Title
L5-02	3	Orbiter
L5-02-01	4	System Engineering
L5-02-01-01	5	Systems Analysis and Definition
L5-02-01-02	5	Systems Effectiveness
L5-02-01-03	5	Test Requirements and Definition
L5-02-01-04	5	Interface Control
L5-02-01-05	5	Safety Assurance
L5-02-01-06	5	Reliability Assurance
L5-02-01-07	5	Quality Assurance
L5-02-01-08	5	Sustaining Engineering
L5-02-02	4	Structures
L5-02-02-01	5	Body Structure
L5-02-02-02	5	Aerodynamic Surfaces
L5-02-02-03	5	Thermal Protection System (TPS)
L5-02-02-04	5	Landing Gear System
L5-02-02-05	5	Docking System
L5-02-02-06	5	Payload Deployment and Retrieval
L5-02-02-07	5	Separation/Attachment System
L5-02-03	4	Propulsion Systems
L5-02-03-01	5	Main Propulsion System
L5-02-03-02	5	Attitude Control Propulsion (ACPS)
L5-02-03-03	5	Orbit Maneuver Propulsion (OMPS)
L5-02-03-04	5	Airbreathing Propulsion System
L5-02-03-05	5	Cryogenic Systems

WBS Code	WBS Level	Title
L5-02-04	4	Power System
L5-02-04-01	5	Electrical Power
L5-02-04-02	5	Mechanical Power
L5-02-05	4	Avionics
L5-02-05-01	5	Avionics System Engineering & Integ.
L5-02-05-02	5	Data Managements
L5-02-05-03	5	Guidance, Navigation and Control System
L5-02-05-04	5	Communication & Tracking
L5-02-05-05	5	Display and Controls
L5-02-05-06	5	Electrical Power Distribution & Control
L5-02-05-07	5	Instrumentation System (Operational)
L5-02-05-08	5	Software
L5-02-06	4	Environmental Control/Life Support System (EC/LSS)
L5-02-06-01	5	Environmental Control
L5-02-06-02	5	Life Support
L5-02-06-03	5	Thermal Control
L5-02-06-04	5	Extravehicular/Intravehicular Activity
L5-02-07	4	Crew Station/Passenger Accomodations
L5-02-07-01	5	Crew Cabin Accomodations
L5-02-07-02	5	Crew /Passenger Accomodations
L5-02-08	4	Flight Controls

WBS Code	WBS Level	Title
L5-02-09	4	Manufacturing Assembly and Checkout
L5-02-09-01	5	System Test Articles
	6	Ground Test Articles
	6	Flight Test Hardware
	6	Ground Support Equipment
L5-02-09-02	5	Tooling
L5-02-10	4	Ground Tests
L5-02-10-01	5	Development Tests
L5-02-10-02	5	Acceptance Tests
L5-02-10-03	5	Certification Tests
L5-02-11	4	Facilities
L5-02-11-01	5	Ground Tests
L5-02-11-02	5	Manufacturing
L5-02-11-03	5	Administrative
L5-02-11-04	5	Engineering
L5-02-12	4	Orbiter System Support
L5-02-12-01	5	Launch & Support Equipment
L5-02-12-02	5	Checkout Equipment
L5-02-12-03	5	Handling & Transportation
L5-02-12-04	5	Servicing Equipment
L5-02-12-05	5	Test Equipment
L5-02-12-06	5	Logistics
L5-02-12-07	5	Manuals & Technical Data
L5-02-12-08	5	Propellants and Gases
L5-02-12-09	5	Onboard Test Support Equipment
L5-02-12-10	5	Production Support
L5-02-12-11	5	Auxiliary Equipment

WBS Code	WBS Level	Title
L5-02-13	4	Training
L5-02-13-01	5	Trainers and Equipment
L5-02-13-02	5	Simulation Support
L5-02-13-03	5	System Training Support
L5-02-14	4	Payload Accommodations
L5-02-14-01	5	Mechanical Accommodation
L5-02-14-02	5	Power Provisions
L5-02-14-03	5	Information & Data Management Equipment
L5-02-14-04	5	Payload Thermal Control
L5-02-14-05	5	Payload Bay Special Equipment
L5-02-15	4	Government Furnished Property (GFP)
L5-02-15-01	5	Government Furnished Data
L5-02-15-02	5	Government Furnished Equipment
L5-02-15-03	5	Government Furnished Services
L5-02-15-04	5	Government Furnished Facilities
L5-02-16	4	Orbiter Program Management
L5-02-16-01	5	Program Control
L5-02-16-02	5	Program Plans
L5-02-16-03	5	Configuration Management
L5-02-16-04	5	Data Management (Documentation)
L5-02-16-05	5	Interface Control
L5-02-16-06	5	Subcontract Management
L5-02-16-07	5	Performance Management
L5-02-16-08	5	Commonality Management
L5-02-16-09	5	Logistics Management
L5-02-16-10	5	GFP Management

WBS Code	WBS Level	Title
L5-03	3	Reusable Booster
L5-03-01	4	Systems Engineering
L5-03-01-01	5	Systems Analysis & Definition
L5-03-01-02	5	Systems Effectiveness
L5-03-01-03	5	Test Requirements & Definition
L5-03-01-04	5	Interface Control
L5-03-01-05	5	Safety Assurance
L5-03-01-06	5	Reliability Assurance
L5-03-01-07	5	Quality Assurance
L5-03-01-08	5	Sustaining Engineering
L5-03-02	4	Structures
L5-03-02-01	5	Body Structure
L5-03-02-02	5	Aerodynamic Surfaces
L5-03-02-03	5	Thermal Protection System (TPS)
L5-03-02-04	5	Landing Gear System
L5-03-02-05	5	Main Propulsion Tanks
L5-03-02-06	5	Separation/Attachment System
L5-03-03	4	Propulsion Systems
L5-03-03-01	5	Main Propulsion System
L5-03-03-02	5	Attitude Control Propulsion (ACPS)
L5-03-03-03	5	Airbreathing Propulsion System
L5-03-04	4	Power System
L5-03-04-01	5	Electrical Power
L5-03-04-02	5	Mechanical Power

WBS Code	WBS Level	Title
L5-03-05	4	Avionics
L5-03-05-01	5	Avionics System Engineering & Integ.
L5-03-05-02	5	Data Management
L5-03-05-03	5	Guidance, Navigation and Control System
L5-03-05-04	5	Communication & Tracking
L5-03-05-05	5	Display and Controls
L5-03-05-06	5	Electrical Power Distribution & Control
L5-03-05-07	5	Instrumentation System (Operational)
L5-03-05-08	5	Software
L5-03-06	4	Environmental Control/Life Support System (EC/LSS)
L5-03-06-01	5	Environmental Control
L5-03-06-02	5	Life Support
L5-03-06-03	5	Thermal Control
L5-03-07	4	Crew Station Accommodations
L5-03-07-01	5	Crew Cabin Accommodations
L5-03-07-02	5	Crew Accommodations
L5-03-08	4	Flight Controls

WBS Code	WBS Level	Title
L5-03-09	4	Manufacturing Assembly and Checkout
L5-03-09-01	5	System Test Articles
	6	Ground Test Articles
	6	Flight Test Hardware
	6	Ground Support Equipment
L5-03-09-02	5	Tooling
L5-03-10	4	Ground Testing
L5-03-10-01	5	Development Tests
L5-03-10-02	5	Acceptance Tests
L5-03-10-03	5	Certification Tests
L5-03-11	4	Facilities
L5-03-11-01	5	Ground Test
L5-03-11-02	5	Manufacturing
L5-03-11-03	5	Administrative
L5-03-11-04	5	Operational
L5-03-11-05	5	Flight Test
L5-03-12	4	Booster System Support
L5-03-12-01	5	Launch & Support Equipment
L5-03-12-02	5	Checkout Equipment
L5-03-12-03	5	Handling & Transportation
L5-03-12-04	5	Servicing Equipment
L5-03-12-05	5	Test Equipment
L5-03-12-06	5	Logistics
L5-03-12-07	5	Manuals & Technical Data
L5-03-12-08	5	Propellants and Gases

WBS Code	WBS Level	Title
L5-03-12-09	5	Onboard Test Support Equipment
L5-03-12-10	5	Production Support
L5-03-12-11	5	Auxiliary Equipment
L5-03-13	4	Training
L5-03-13-01	5	Trainers and Equipment
L5-03-13-02	5	Simulation Support
L5-03-13-03	5	System Training Support
L5-03-14	4	Government Furnished Property (GFP)
L5-03-14-01	5	Government Furnished Data
L5-03-14-02	5	Government Furnished Equipment
L5-03-14-03	5	Government Furnished Services
L5-03-14-04	5	Government Furnished Facilities
L5-03-15	4	Booster Program Management
L5-03-15-01	5	Program Control
L5-03-15-02	5	Program Plans
L5-03-15-03	5	Configuration Management
L5-03-15-04	5	Data Management (Documentation)
L5-03-15-05	5	Interface Control
L5-03-15-06	5	Subcontract Management
L5-03-15-07	5	Performance Management
L5-03-15-08	5	Commonality Mangement
L5-03-15-09	5	Logisitics Management
L5-03-15-10	5	GFP Management

WBS Code	WBS Level	Title
L5-04	3	Main Engine (GFE)
L5-05	3	Core Avionics Integration (Subsystems provided by the Government for integration into the orbiter and booster)
L5-06	3	Operations
L5-06-01	4	Flight Test Operations
L5-06-01-01	5	Orbiter Horizontal Flight Test
L5-06-01-02	5	Booster Horizontal Flight Test
L5-06-01-03	5	Orbiter Vertical Flight Test
L5-06-01-04	5	Booster Vertical Flight Test
L5-06-01-05	5	Launch Vehicle (Combined) Vertical Test
L5-06-01-06	5	Flight Test Operations Facilities
L5-06-01-07	5	Test Operations Support
L5-06-01-08	5	Propellants and Gases
L5-06-01-09	5	Test Operations Management
L5-06-02	4	Flight Operations
L5-06-02-01	5	Flight Operations Integration
L5-06-02-02	5	Flight Operations Flight Support
L5-06-02-03	5	Flight Operations Ground Support
L5-06-02-04	5	Training
L5-06-02-05	5	Flight Operations Facilities
L5-06-02-06	5	Propellants and Gases
L5-06-02-07	5	Flight Operations Management

WBS Code	WBS Level	Title
L5-07	3	External Tanks
L5-07-01	4	External Tank Integration
L5-07-01-01	5	Systems Integration
L5-07-01-02	5	Systems Engineering
L5-07-02	4	Structures
L5-07-02-01	5	Airframe Integration
L5-07-02-02	5	Tank Structure - O_2
L5-07-02-03	5	Tank Structure - H_2
L5-07-02-04	5	Support Structures
L5-07-02-05	5	Electro-Mechanical Systems
L5-07-03	4	Propulsion System
L5-07-03-01	5	Propulsion System Integration
L5-07-03-02	5	Fuel Delivery System
L5-07-03-03	5	Oxidizer Delivery System
L5-07-04	4	Thermal Protection System

WBS Code	WBS Level	Title
L5-07-05	4	Instrumentation System
L5-07-06	4	Manufacturing, Assembly, and Checkout
L5-07-06-01	5	System Test Articles
L5-07-06-02	5	Tooling
L5-07-07	4	Ground Test
L5-07-07-01	5	Development Tests
L5-07-07-02	5	Acceptance Tests
L5-07-07-03	5	Certification Tests
L5-07-08	4	Facilities
L5-07-08-01	5	Ground Test
L5-07-08-02	5	Manufacturing
L5-07-08-03	5	Administrative
L5-07-08-04	5	Engineering
L5-07-09	4	External Tank System Support
L5-07-09-01	5	Launch & Support Equipment
L5-07-09-02	5	Monitoring Equipment
L5-07-09-03	5	Handling & Transportation
L5-07-09-04	5	Servicing Equipment
L5-07-09-05	5	Test Equipment
L5-07-09-06	5	Logistics
L5-07-09-07	5	Manuals & Technical Data
L5-07-09-08	5	Propellant & Gases
L5-07-09-09	5	Production Support
L5-07-09-10	5	Auxiliary Equipment

WBS Code	WBS Level	Title
L5-07-10	4	External Tank Program Management
L5-07-10-01	5	Program Control
L5-07-10-02	5	Program Plans
L5-07-10-03	5	Configuration Management
L5-07-10-04	5	Data Management (Documentation)
L5-07-10-05	5	Interface Control
L5-07-10-06	5	Subcontract Management
L5-07-10-07	5	Performance Management
L5-07-10-08	5	Logistics Management
L5-07-10-09	5	GFP Management
L5-08	3	Expendable Boosters
L5-08-01	4	Expendable Booster Integration
L5-08-02	4	Solid Rocket Motors (SRM's)
L5-08-03	4	Structures
L5-08-04	4	TVC System
L5-08-05	4	TPS
L5-08-06	4	Avionics and Control
L5-08-07	4	Instrumentation
L5-08-08	4	Separation (Staging System)
L5-08-09	4	Manufacturing
L5-08-10	4	Ground Test
L5-08-11	4	Facilities
L5-08-12	4	Systems Support
L5-08-13	4	Expendable Booster Management

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